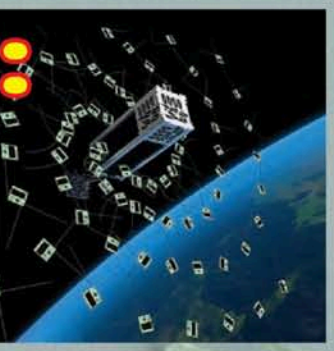
SILICON CHIP

The BEST DIY Projects!

JANUARY 2018
ISSN 1030-2662
01
9 771030 266001
PP255003/01272
$9.95* NZ$12.90 INC GST

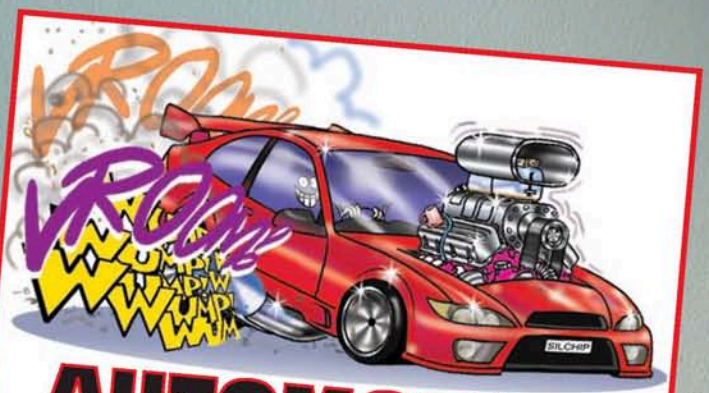
FEATURE:

Huge swarms of micro satellites are watching YOU from out in SPACE!



BUILD YOUR OWN THEREMIN

And make Sensational Music!



AUTOMOTIVE DC FAN SPEED CONTROLLER

... with hundreds of other applications!

Jaycar Electronics
Better, More Technical

duinotech
PROJECT OF THE MONTH

Our very own specialists are developing fun and challenging Arduino®-compatible projects for you to build every month, with special prices exclusive to Nerd Perks Club Members.

BUILD YOUR OWN TINY GAME AND PROGRAM IT!

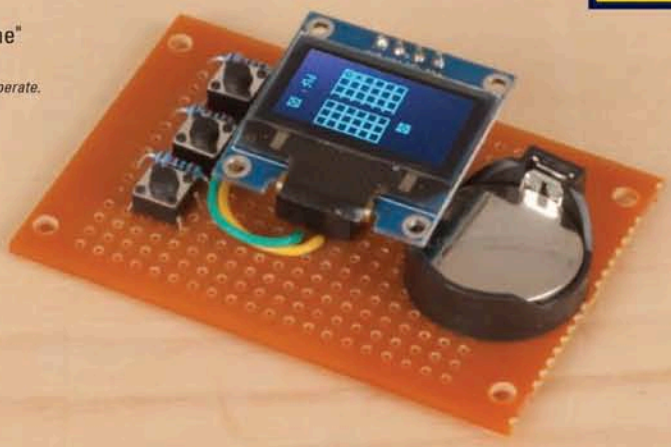
The ATTiny85 IC is great for making small (Ok, let's call them Tiny) Arduino®-based projects. It supports Arduino® and is super easy to use. Here we show you how to build a tiny game to play using a handful of components and OLED screen. We've designed it to run a version of the popular four-in-a-row game, but you can also download a version of Tetris®.
Once you have mastered those you could even write your own.
We also show how to build a simple in-circuit programmer for the ATTiny85 . See bundle below "Program Your Own Game" for parts needed.

Some soldering required. Project requires a button cell battery (SB-2522 not included) to operate. This project is not a toy and should be kept out of the reach of children.

NERD PERKS CLUB OFFER
BUNDLE DEAL
$29.95
SAVE OVER 35%

VALUED AT $47.38

SEE STEP-BY-STEP INSTRUCTIONS AT:
jaycar.com.au/tiny85-game



WHAT YOU NEED:

1 X ATTINY85 IC 8 PIN	ZZ-8721	$4.95
1 X MINI EXPERIMENTERS BOARD	HP-9556	$4.95
1 X OLED DISPLAY MODULE	XC-4384	$29.95
1 X 40 PIN FEMALE HEADER STRIP	HM-3230	$1.80
3 X 1.4MM SPST MICRO SWITCH	SP-0601	$0.95
1 X 8 PIN IC SOCKET	PI-6500	$0.38
1 X 10K OHM 0.5W METAL FILM RESISTORS	RR-0596	$0.55
1 X BUTTON CELL BATTERY HOLDER	PH-9238	$1.95

SEE OTHER PROJECTS AT: www.jaycar.com.au/arduino

PROGRAM YOUR OWN GAME

You can make a very simple In System Programmer using an UNO Board and some other components, allowing your ATTiny85 to be programmed in circuit. See instructions in project above.

NERD PERKS CLUB OFFER
BUNDLE DEAL
$24.95
SAVE OVER 30%

BUNDLE DEAL
VALUED AT $36.63

UNO BOARD	XC-4410	$29.95
150MM JUMPER LEADS	WC-6024	$5.95
8 PIN IC SOCKET	PI-6500	$0.38
10UF 25VDC CAPACITOR	RE-6070	$0.35

ADD SOUND

$3.95

ACTIVE BUZZER MODULE
XC-4424
The easy way to add sound to your project. Hook up a digital pin and ground, and use the tone() function to get your Arduino® beeping.

ADD JOYSTICK

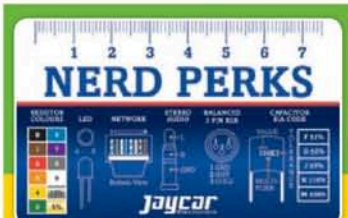
$5.95

JOYSTICK MODULE
XC-4422
This handy module gives you X & Y axis control for your Arduino® project. Provides a small game pad style joystick.

NERD PERKS CLUB MEMBERS RECEIVE:

10% OFF
RACK MOUNT CABINETS*

**Applies to 19" Rack Mount cabinets, Swing Frame Rack Enclosures, Pro Grade 19" Rack Style Equipment Enclosures. Excludes accessories.*



EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS GIFT CARD ONCE YOU REACH 500 POINTS!
Conditions apply. See website for T&Cs

REGISTER ONLINE TODAY BY VISITING:
www.jaycar.com.au/nerdperks

Contents

Vol.31, No.1; January 2018

SILICON CHIP

www.siliconchip.com.au

Features & Reviews

14 Monitoring our world – and beyond – with tiny satellites

Every year, hundreds of satellites are launched to watch over us from space. Some are huge . . . but many are really tiny, some as small as 10 x 10 x 10cm. Here's the latest on these miniature marvels – by Dr David Maddison

78 El Cheapo Modules 12: 2.4GHz Wireless Data Modules

The nRF24L01+ chip makes a complete 2.4-2.5GHz wireless data transceiver capable of up to 2Mb/s over modest distances. It has a standard SPI interface, making it easy to use with any microcontroller – by Jim Rowe

Constructional Projects

24 Make your own Theremin – then make music!

It's been around for almost 100 years – but now you can make your own low-cost version and produce the eerie sounds characteristic of this instrument. Even the volume plate is part of the PCB – by John Clarke

36 The Lathe-E-Boy: high power Lathe Controller

Combine our Induction Motor Speed Controller and a Micromite Plus Explore 100 and you have an easy way to control a lathe, automatically adjusting its speed to suit the material being turned – by Peter Bennet and Nicholas Vinen

44 Arduino LC Meter Shield Kit

Altronics have just released a complete LC Meter kit based on our June '17 Arduino LC Meter. It's easy to build and can be used in stand-alone mode or in conjunction with the Mega Box, described last month – by Bao Smith

64 High Power DC Fan Controller has loads of applications

This proportional speed controller was designed to run an intercooler fan in a high-power V8 but could be used with virtually any DC motor requiring accurate speed control. It's compact, light and easy to build – by Nicholas Vinen

Your Favourite Columns

58 Serviceman's Log

The dodgy stereo recorder that wasn't stereo – by Dave Thompson

84 Circuit Notebook

(1) Precision Fridge Door Alarm
(2) Debugging a failing electric motor
(3) Op Amp Antenna Preamplifier

88 Vintage Radio

"Restoring" a pile of hydrated ferric oxide. It will never work again – but it looks great – by Associate Professor Graham Parslow

Everything Else!

2 Editorial Viewpoint
4 Mailbag – Your Feedback
57 Product Showcase
94 Ask SILICON CHIP
100 SILICON CHIP Online Shop
103 Market Centre
104 Advertising Index
104 Notes and Errata

Swarms of tiny satellites, many smaller than this page, are watching you from space. – Page 14

The Theremin: inexpensive and easy to build . . . and if you master it, can make really beautiful music! But can you master it? – Page 24

If you use a lathe, you'll know how important good speed control is! The Lathe-E-Boy can do it for you – Page 36

Altronics have just released this superb LC Meter shield kit, based on the June 2017 SILICON CHIP project – Page 44

We designed this device for auto fan control but then realised it has many other uses! – Page 64

When is a vintage restoration not a vintage restoration? When it starts out as a pile of junk which can never work again! The "restoration" is all for show – but gee it looks good . . . – Page 88

Find us on Facebook

www.facebook.com/siliconchipmagazine

SILICON CHIP
www.siliconchip.com.au

Publisher
Leo Simpson, B.Bus., FAICD

Editor
Nicholas Vinen

Technical Editor
John Clarke, B.E.(Elec.)

Technical Staff
Ross Tester
Jim Rowe, B.A., B.Sc
Bao Smith, B.Sc

Photography
Ross Tester

Reader Services
Ann Morris

Advertising Enquiries
Glyn Smith
Phone (02) 9939 3295
Mobile 0431 792 293
glyn@siliconchip.com.au

Regular Contributors
Dave Thompson
David Maddison B.App.Sc. (Hons 1), PhD, Grad.Dip.Entr.Innov.
Geoff Graham
Associate Professor Graham Parslow
Ian Batty

Cartoonist
Brendan Akhurst

SILICON CHIP is published 12 times a year by Silicon Chip Publications Pty Ltd. ACN 003 205 490. ABN 49 003 205 490. All material is copyright ©. No part of this publication may be reproduced without the written consent of the publisher.

Subscription rates: $105.00 per year in Australia. For overseas rates, see our website or the subscriptions page in this issue.

Editorial office:
Unit 1 (up ramp), 234 Harbord Rd, Brookvale, NSW 2100.
Postal address: PO Box 139, Collaroy Beach, NSW 2097.
Phone (02) 9939 3295.
E-mail: silicon@siliconchip.com.au

Printing and Distribution:
bluestar
Derby Street, Silverwater, NSW 2148.

ISSN 1030-2662
Recommended & maximum price only.

Editorial Viewpoint

Autonomous vehicles will need to be very secure

Billions of dollars are currently being spent in an attempt to create passenger vehicles which can drive themselves on public roads. Some of these are already being trialled in Australia and in other countries.

Furthermore, a number of recent articles have suggested that these autonomous vehicles will need to be networked in order to operate efficiently.

No doubt many of them will be in communication with their manufacturers or operators via mobile phone networks, in the same way that the Nissan Leaf and Tesla vehicles "phone home" for software updates, battery monitoring and so on.

But this creates a huge problem if the security isn't 100% foolproof. Hackers could easily steal your car by simply telling it to drive itself away. Worse, people could be kidnapped by being locked in their moving vehicles while they are redirected to a new destination or even held ransom with the threat of being driven off a cliff!

And let's not even think about the terrorism implications of any security holes in autonomous vehicles, especially if they become known when there is already a large fleet of vehicles on the roads.

You may think this is only a theoretical risk but security researchers have already demonstrated remotely taking control of a vehicle and it wasn't even an autonomous one. It was just an ordinary Jeep with a flaw in the security of its entertainment system. For details, see: **www.wired.com/2015/07/hackers-remotely-kill-jeep-highway**

Almost unbelievably, this was connected with the vehicle control systems in such a way that a hacker with access to the entertainment system could cause the vehicle to crash.

Nor was this an isolated incident; commercial aircraft have been found to have large security flaws, allowing passengers to gain access to critical flight computers through their movie screens! Unbelievable! See: **www.wired.com/2015/05/feds-say-banned-researcher-commandeered-plane**

Pretty much every day now, we hear about the latest security flaw. Recently, a huge problem with WiFi encryption was discovered, even though we're now on the third or fourth different scheme as each one attempts to provide better security. More recently, it was discovered that a macOS update allowed anyone with access to a computer to get administrator access with just a few mouse clicks.

Frustratingly, many of these security flaws turn out to be dumb mistakes, of the kind that an experienced engineer or programmer should not make. Who thinks it's a good idea (or even necessary) for the entertainment system on an aircraft to share any commonality with the avionics? Why do we still have security software and operating systems with rookie errors like buffer overflows?

This will all have to be well and truly addressed before we can trust autonomous vehicles with our lives. The software will also need to be able to cope gracefully with GPS jamming/spoofing, infrastructure failures (network outages, power outages), road marking vandalism and other non-hacking activities which could deliberately or accidentally cause a self-driving vehicle to become confused or lost.

While I've no doubt working on one of these projects would be exciting, it must also be daunting, knowing all the challenges which must be overcome for the technology to come to fruition. They must be overcome, otherwise no one will be safe from rogue vehicles which could even deliberately smash into your home or chase you along the foot path.

Are you worried? You should be.

Nicholas Vinen

Design With The Best

Digi-Key® ELECTRONICS

AUSTRALIA
DIGIKEY.COM.AU
1800 285 719

NEW ZEALAND
DIGIKEY.CO.NZ
800 449 837

6 MILLION+ PRODUCTS ONLINE | 650+ INDUSTRY-LEADING SUPPLIERS | 100% AUTHORIZED DISTRIBUTOR

*Australia: A shipping charge of $24.00 AUD will be billed on all orders of less than $60.00 AUD. A shipping charge of $20.00 USD will be billed on all orders of less than $50.00 USD. All orders are shipped via UPS, Federal Express, or DHL for delivery within 3-4 days (dependent on final destination). No handling fees. All prices are in Australian dollar or United States dollar. **New Zealand:** A shipping charge of $26.00 (NZD) will be billed on all orders of less than $66.00 (NZD). A shipping charge of $20.00 USD will be billed on all orders of less than $50.00 USD. All orders are shipped via UPS for delivery within 3-4 days (dependent on final destination). All prices are in New Zealand dollar or United States dollar. Digi-Key is an authorized distributor for all supplier partners. New product added daily. Digi-Key and Digi-Key Electronics are registered trademarks of Digi-Key Electronics in the U.S. and other countries. © 2018 Digi-Key Electronics, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA

eda MEMBER ecsn member CEDA

MAILBAG – your Feedback

Letters and emails should contain complete name, address and daytime phone number. Letters to the Editor are submitted on the condition that Silicon Chip Publications Pty Ltd may edit and has the right to reproduce in electronic form and communicate these letters. This also applies to submissions to "Ask SILICON CHIP", "Circuit Notebook" and "Serviceman".

Economics of an off-grid solar system

A lot of people seem to think that solar and batteries will solve our energy problems in the future and that it will be possible for many households to go "off grid" and be completely independent.

Why don't you do an article on what it would cost for a typical Australian family, say using the so-called average of 25 kilowatt hours per day, to put in a solar system that was completely off-grid and did not include a diesel generator?

I think the answer would be fascinating. When I last looked at it, you would have to almost cover your whole block of land with solar cells, not just the roof and the cost was prohibitive – something like between two and four times the typical electricity cost per day.

Of course the electricity is free from the Sun, but you have to borrow the money and write off the cost of the battery system and the solar cells.

Remember, we can have four or five days of virtually no Sun in Sydney. So that means you need to store at least 125 kilowatt hours of energy and as the battery normally can't be taken to less than 50%, that means battery storage of 250 kilowatt hours.

I think the cost is enormous. Surely someone should do some simple figures on this just to show what it would cost to basically go off-grid. Yes, lots of people have solar cells now because they are being cross-subsidised by those who don't – mostly the poor pensioners.

Dick Smith,
via email.

Comment: You could possibly manage with a 10kW solar array but that would be larger than most home roofs could accommodate. A 10kW inverter/battery charger might also manage but the battery would be a killer, even with the deep discharge possible with lithium batteries.

To cope for five days without Sun and without a diesel generator is going to need a lithium battery bank (eg, multiple Tesla Powerwalls or equivalent) costing at least $90,000; maybe a lot more. Then you have the cost of the solar panels, inverters and the high cost of an approved installation by licensed installers.

The fact that you are going off-grid does not avoid the need to meet stringent electrical standards, if only to be able to insure the dwelling. All up, the total job could leave little change from $150,000.

And as you suggest, you have to borrow the money and allow for the eventual replacement of batteries, panels and inverters. By the way, the smaller the battery, the harder it will have to be "worked" (ie, deeper charge/discharge cycles) and therefore it will have a shorter life.

The cost of going "off-grid" completely is simply far too expensive for any typical Australian household to contemplate.

We should emphasise that the above is a "back-of-the-envelope" calculation and an actual cost estimate of a real-world off-grid system to meet your requirements of 25kWh/day, five days without Sun and no diesel backup would need a lot of technical info from experienced installers.

It is not possible to make useful comparisons with existing solar systems in cities as most are grid-tied and have had massive cross subsidies. As you say, these are paid for by people who cannot afford to or do not have space for roof-top solar systems, and this includes most of those people who live in home units.

Congratulations on 30 years of SILICON CHIP

When we arrived in Australia in 1988, we first lived around the corner from your current office, in Freshwater (then known as Harbord), just up the street from the surf club; a beautiful spot to start life in Australia. We were very taken by the place and the people.

I soon started at Telectronics in Lane Cove and had seven good years there with Bill Blackburn doing components engineering. That was just before it got into trouble.

Last-minute feature added to Touchscreen Altimeter

I just received the December issue and as usual it was a great read! I read the Altimeter/Micromite project and noticed there doesn't seem to be a facility to alter the barometric pressure at sea level.

Pilots flying from A to B usually receive the ATIS (Airport Terminal Information Service) broadcast from the destination airport, which tells them the corrected barometric pressure at sea level (abbreviated QNH). This allows them to correct their altimeter in flight to suit the actual pressure at that time and could be critical prior to landing.

Your project appears to allow for the ground altitude to be zeroed, which is fine if you are landing at the same location within a reasonable time period, but possibly not for a different location with different weather.

I haven't built this unit so I am unable to verify if this is the case, however the text makes no mention of setting the QNH.

Bruce Boardman,
Highfields, Qld.

Comment: Thanks for your letter; we realised that changes in barometric pressure might cause a problem.

Jim Rowe has now added a feature to the software which allows you to enter the barometric pressure at sea level while the unit is in use.

The updated software is now available for download from our website, along with the BackPack kit and front panel.

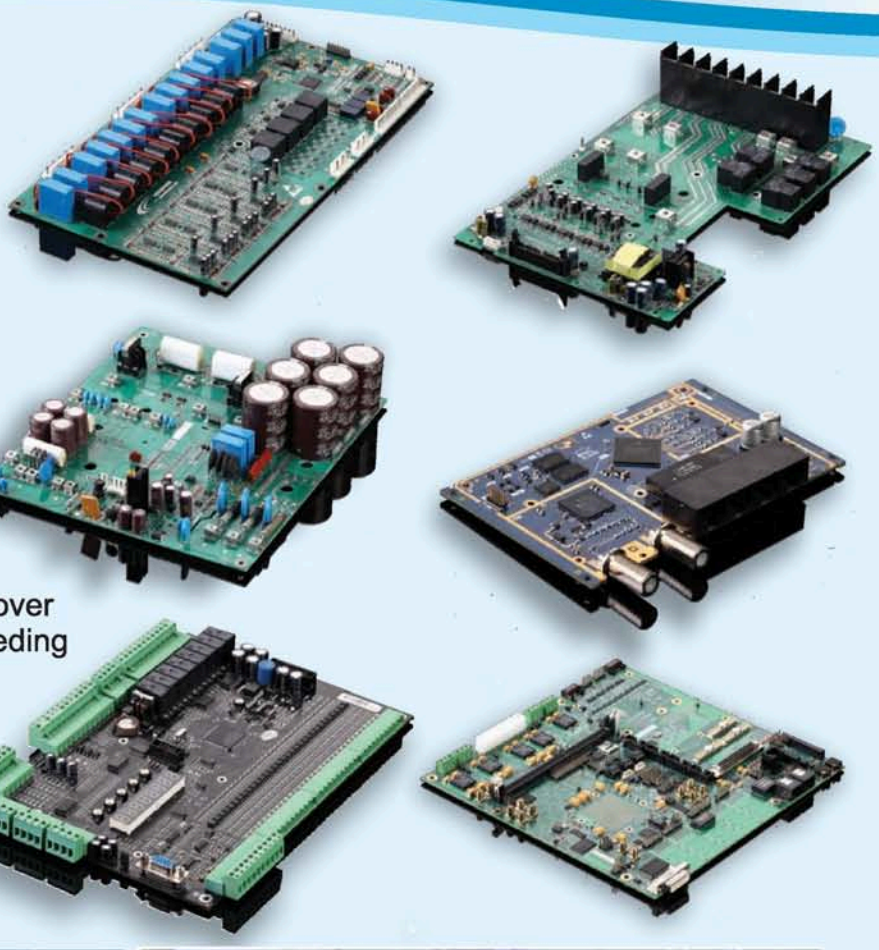
LEACH

EMS SINCE 1999

Your most reliable electronic contract manufacturing partner

Engineering expertise in complex PCB assembly for industrial control, medical/health care, Telecom, Energy, traffic signs etc.

LEACH offer:
*OEM & ODM service
*Components global procurement
*Prototype and NPI
*PCB Assembly (SMT/DIP)
*AOI & ICT functional testing
*Cable assembly and Box-build
*Global Logistics



Covering an area of 2000m^2, we have over 100 employees and annual sales exceeding $US10,000,000, over 80% of which is exported worldwide.
The well-equipped facilities and excellent quality control throughout all stages of production enables LEACH to guarantee total customer satisfaction.

SMT LINES

REFLOW OVEN

LEACH (HK) CO. / LEACH (SZ) CO. LTD

Address: Floor 2, Block 2, Wandi Industrial Park,
Xikeng Laocun, Guanlan, Longhua, Shenzhen, China 518110
TEL: +86 755 89580259 FAX: +86 755 89504192
E-MAIL: info@leach-pcba.com

Want to work for Australia's Electronics Magazine

SILICON CHIP

If you live, breathe and sleep electronics you could be just the person we're looking for. While formal qualifications are well regarded, don't let a lack of letters after your name put you off, if you have the experience we're looking for.

The right person will certainly have skills in the following areas:

- **Analog and digital circuit design from concept to completion**
- **Circuit analysis and debugging**
- **PCB layout (we use Altium Designer)**
- **PC software development and embedded programming**
- **Operating electronic test equipment**
- **Mechanical design**

But most of all, you'll have the ability to write interesting articles (in English) describing what you've built and how SILICON CHIP readers can reproduce what you've done. You will have seen the style of SILICON CHIP articles – you're almost certainly an existing SILICON CHIP reader.

If you have skills in other areas which would help SILICON CHIP appear each month, tell us about them too: skills such as sub-editing, desktop publishing/layout, circuit drawing, photography, image processing, technical support/customer service (via telephone), project management, parts ordering and management, database administration, website design/programming and operating CNC equipment.

We don't expect you to have all these skills – but we'll help you to develop them as required.

You'll need to be highly self-motivated and able to work well by yourself as well as in a small team. Being able to work to the rigorous deadlines of a monthly magazine is vital.

Candidates will be given a six-month trial with a permanent position at the successful conclusion.

If you think you have what it takes, email your resume/CV (along with contact details!) to **silicon@siliconchip.com.au**

Anyway, I just wanted to congratulate you on a continued effort and good publication.

Peter Wagner Hansen,
Ocean Shores, NSW.

Miraculous new battery technology

Like Derek Mitchell ("Cautious but optimistic about electric vehicles", SILICON CHIP, Mailbag, November 2017 pp14-16), I am also optimistic about EVs. In Derek's letter he says that "a large fully electric vehicle can comfortably charge overnight".

For me, this is too long and the main reason I haven't bought an EV. However, there is a new battery technology emerging that I only heard about recently that could solve this problem.

The new batteries are based on aluminium ion technology and are being researched by Taiwan's Industrial Technology Research Institute. These new batteries have many advantages over lithium-ion batteries. They will be cheaper because aluminium is a very common element, easily obtained at low cost.

They can withstand 10,000 charge/discharge cycles. They are safe with no risk of fire. They have high power density and research is continuing to improve this.

During a trial on a commuter bus the batteries were recharged in six minutes! This means the charge time for a car would be just a minute or two; quicker than filling your tank with petrol.

This is the sort of battery I want for my EV. I was hoping SILICON CHIP could dig a little deeper into this story and maybe do an article on the new batteries, as they sound almost miraculous. They also won a 2017 Edison prize in the energy category.

R. Moulis
Hackett ACT.

Response: we will see what we can find out about this. It sounds really good and could definitely be a game-changer but unfortunately, many of the whizz-bang new technologies we hear about (especially regarding batteries) never seem to make it to market for one reason or another.

Mix-up with Holden production plants

Silly me – I always thought that Elizabeth where GMH had a manufacturing plant was in South Australia, not Victoria (Editorial, December 2017 issue).

Congratulations on your 30 years of very successful and worthwhile publication – although I am no longer a subscriber now, it is always a worth while read, I have enjoyed it immensely.

Don Jackson
Pakenham, Vic.

Nicholas responds: You are right, and you aren't the only person to point this out. I got the Holden vehicle assembly plant (Elizabeth, SA), which recently shut down, mixed up with the Holden engine plant (Port Melbourne, Vic), which closed last year.

The Ford plants, which also closed last year, were in Broadmeadows (vehicle assembly) and Geelong (engine assembly), Vic.

Thanks for your kind words.

Disagreement on some aspects of Super-7 AM Radio operation

Thank you for publishing your "Super-7" AM Radio project. It's refreshing to see the reboot of a classic "trannie". I have a few issues with it, though:

1. You state "there are several reasons for using IF transformers" and go on to describe them "filtering out unwanted frequencies so that the transistors don't waste power amplifying unwanted signals..."

This is puzzling; most "unwanted signals" are filtered out by the antenna tuned circuit at the input to the set.

Also, since the IF amplifiers work in Class A and thus draw constant current from the supply, it's hard to see how transistors would "waste power" on signals that probably haven't made it into the converter stage, let alone to the primary of the first IFT.

Your descriptions of IF transformers provision of filtering/bandpassing and impedance transformation are sufficient to justify their employment.

2. In your panel feature, you correctly describe the "heterodyne" component of the word "superheterodyne", but then confusingly describes "super" as meaning that "the second frequency is higher than the frequency of interest".

This is wrong both in definition and in practice.

Firstly, the term was originally "supersonic heterodyne", meaning simply that heterodyning occurred at supersonic frequencies. Secondly, "oscillator-under" designs do exist, principally in HF/VHF/UHF designs.

The Eddystone 770U, tuning from 150~500MHz, has its local oscillator

on the low side for its highest tuning band of 400~500MHz.

This gives greater stability, as a high-side LO would have to tune up to 550MHz, rather than the actual 350~450MHz. Radiotron Designer's Handbook Edition 4, chapter 25, part 2(ii) discusses low-side versus high-side injection "at short waves".

3. The "subheterodyne" (of which the Eddystone 770U is a partial example) works perfectly well, and low-side injection is fine in theory.

Your writer has missed out on the principal reason why low-side LO injection is not used at AM Broadcast frequencies and the low end of the High Frequency band.

Low-side injection is impractical on the broadcast band, as the LO would need to tune from 535 – 455 = 80kHz to 1605 – 455 = 1105kHz.

This is a 13.8:1 tuning range, demanding a range in (say) capacitor tuning capacitance of around 191:1! High-side injection gives a LO tuning range of 990~2060kHz, an easily-achievable capacitance range of only about 4.3:1.

Your writer is correct that low-side injection would put the LO smack bang into the IF band as it tuned past 910kHz (ie, 910 – 455 = 455!), and would blank out reception of any stations around this point. The rest of the paragraph ("ghost stations") is rather more complicated. The simpler explanations (tuning capacitor range and IF blanking) are surely sufficient.

4. Your use of a schottky diode for the demodulator is innovative, and offers a useful alternative to increasingly-scarce germanium diodes. But I notice that you've not used the preferred design for output stage biasing.

You would be aware of the superior performance of the V_{BE} multiplier as a circuit capable of compensating temperature, supply voltage changes and output transistor replacement.

Given the thoroughness of the rest of the design, it's a pity you missed out on using the preferred biasing circuit. Such use would also have given constructors an insight into standard practice.

5. You note correctly that DC potentials across volume controls are undesirable, but your design allows a DC potential, existing at the demodulator's anode, to be applied across VR1.

Your text also states prevention of DC across the volume pot as the reason for the placement of the 10µF coupling capacitor. There is a more compelling reason for this component – its absence would connect the volume pot's wiper directly to the base of Q4, making operation of the audio amplifier impossible due to shunting Q4's bias potential to ground.

6. You correctly note the connection of Q5's 1kΩ load resistor to the speaker circuit providing an effectively high load impedance for Q5. But there is a far more important reason for this bootstrap circuit.

Q7's base must be pulled near to ground potential on the maximum negative-going half-cycle of the output signal, an excursion of some -4.5V. Assuming an 8Ω speaker, this demands around half an amp collector current in Q7. Assuming an h_{FE} of 100, this means some 5mA of Q7 base current.

Were the 1kΩ resistor returned to ground, Q7's base current would be insufficient to give negative swing even if Q5 were totally cut off. But, since the 1kΩ resistor's "speaker" end is taken to some -4.5V at the peak negative swing,

freetronics
www.freetronics.com.au

Love electronics? We sure do! Share the joy: give someone an Experimenters Kit for Arduino:

Includes:

- 48-page printed project guide
- Arduino compatible board / USB cable
- Solderless breadboard
- Sound & Piezo module
- Light sensor module
- Micro servo motor
- Red, green, and RGB LEDs
- Resistors, transistors, and diodes
- Buttons and potentiometer
- ... and more!

Use discount code "SCJAN18" for 20% off until March 2018!

Support the Aussie electronics industry. Buy local at www.freetronics.com.au

Many more boards available for Arduino, Raspberry Pi, and ESP8266 projects: motor controllers, displays, sensors, Experimenters Kits, addressable LEDs, addressable FETs

Arduino based USB Full Colour Cube Kit - visualise, customise and enjoy on your desk!

Australian designed, supported and sold

sufficient base current is supplied to Q7. In this context, any increase in load impedance for Q5 is by far the lesser reason for the bootstrap circuit.

On another note, let me congratulate your very fine magazine on its 30th birthday. By featuring advanced designs alongside vintage radios (and everything between!) and by providing a forum for debate and discussion, I feel that the electronic enthusiast will continue to feel supported and to look forward to a bright and interesting future.

Ian Batty,
Harcourt, Vic.

Leo Simpson responds: Thanks for your comments on the revamped transistor radio. This is actually a modest revision of the AM Radio Trainer from the June & July 1993 issues of SILICON CHIP. I generally agree with your points about the definition of superheterodyne and the pros and cons of high and low side local oscillator injection.

However, I do think that one function of the IF stages is to remove unwanted out-of-band signals since the aerial tuning circuit does not fully remove them. However I agree that no power is "wasted" on signals.

We are quite aware of the advantage of V_{BE} multipliers and have used them on every high performance amplifier we have featured in SILICON CHIP. However, we think the much simpler series diode and trimpot is quite adequate for bias stabilisation in a low power amplifier, as used in this superhet.

We were also aware that there is a DC potential across the volume control potentiometer but is it really quite small. Furthermore, no DC flows through the pot wiper which really would cause a lot of noise every time the volume was adjusted.

In some respects, this circuit largely reflects the design practice used in many transistor radios of the 1960s. Yes, circuit refinements could have been added but they would have given little or no perceptible improvement in performance.

You are also correct in pointing out that the boot-strapped output stage ensures that Q7 has sufficient base current. If boot-strapping had not been provided, the only way to ensure sufficient base current for Q7 would have been to add a constant current load for Q5.

This was never done in cheap radios of the time. In fact, many transistor radios of the period used a pair of PNP germanium transistors in a transformer-coupled class-AB output stage, with a thermistor used for bias compensation.

The radio is already proving quite popular, possibly because it can be assembled into an attractive acrylic case.

Direct electric water heating is definitely not new

Having read the letter in December's issue of SILICON CHIP regarding heating water by passing current through it, I thought you might like further details on the electric jugs you mentioned in your reply.

As a user of vintage appliances, I am quite familiar with the disc type elements and have attached a set of instructions and photos for your interest. The element consists of two stainless steel discs spaced apart by a ceramic insulator, which sits at the bottom of the jug in the usual position.

Of course, the water, as with any open element, becomes live, hence the warning to only use it with earthenware jugs.

Indeed, performance with rainwater is too poor to be of any use. Typically, around 180-200W is all the heating power one gets and the water never boils. With a carefully sized pinch of salt added to the water, the water can be made to boil but it's easy to overdo it and it could then draw over 3kW!

It is not something to be recommend therefore, especially unless the current is monitored. On mains water, which is what these elements are designed for, the power draw is around 1850W. This happens to be similar to the nichrome wire elements normally supplied with these jugs.

Interestingly, the power increases as the water begins to warm up, ending up in my case to be around 2.5kW. It is perhaps fortunate that the water boils faster in this instance so that the slight overload to the jug cord connectors is only for a short time.

The method certainly works but is obviously very dependent on water quality.

Incidentally, for anyone still using these jugs wanting to experiment, the disc type elements (along with the wirewound types) were still available from Tobins the last time I bought some (a couple of years ago).

However, I don't expect them to be available forever – jug elements disappeared from supermarkets and hardware stores about five years ago, so anyone using these jugs would be wise to stock up on replacements while they can.

John Hunter,
Hazelbrook, NSW.

More congratulations from overseas

I have just received the November issue of the magazine. Congratulations to you and all the staff of the SILICON CHIP magazine on 30 successful years in the publishing industry. I wish you all continued success in the coming years.

Mahmood Alimohammadi,
Tehran, Iran.

Error in Vintage Radio circuits

First, may I thank you for your excellent magazine which I have been receiving now for many years. It has helped me keep up with new technology, as I am now advanced in years.

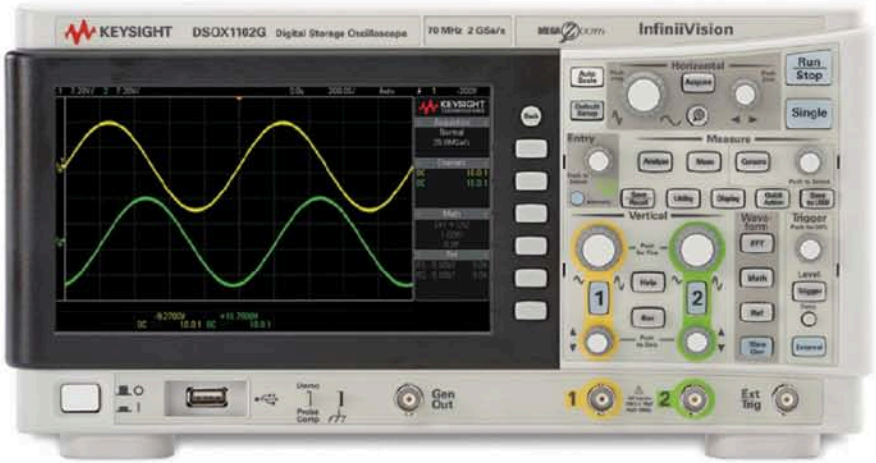
The Vintage Radio column by Ian Batty in the November 2017 issue (www.siliconchip.com.au/Article/10880) has a repeated error in the circuit diagrams on pages 99 and 100: coupling capacitor C4 feeding D1 has been drawn coming off the wrong side of L2. This point is shorted to RF by C6. C4 (100pF) should be off the plate of V1, as there should be no RF at the other end of L2 due to C6.

I do enjoy these Vintage Radio articles and the Serviceman's Log, as I too was a serviceman a long time ago.

Rod Rowe,
Morrinsville, NZ.

The disc-type element that sits at the bottom of the jug. The element is made of two stainless steel discs separated by a ceramic insulator.

Scrap the Toys!



Get a Real Oscilloscope

Model	Description
Bandwidth	50 MHz, 70 MHz, 100 MHz
Channels	2 analog channels
Sample rate	Up to 2 GSa/s
Memory	Up to 1 Mpt per channel
Display	7-inch WVGA
Update rate	50,000 wfms/s
6-in-1 integration	Oscilloscope
	WaveGen built-in 20 MHz function generator (standard on EDUX1002G and DSOX1102G)
	Serial protocol analyzer – option (EDUX1EMBD, DSOX1EMBD, DSOX1AUTO)
	Digital voltmeter – free with product registration
	Frequency counter – standard
	Frequency response analyzer – option (standard on EDUX1002G and DSOX1102G)
Upgradable	Bandwidth, serial protocol analyzer, warranty
Warranty	Standard 3-year, upgradable to 5-year
Calibration interval	5 year
Connectivity	USB host, USB device, BenchVue ready

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

Wagner
ELECTRONICS SUPER STORE
OVER 40 THOUSAND PRODUCTS
ONLINE 1500+ PAGE CATALOGUE
AUSTRALIA WIDE SHIPPING

AUDIO/VISUAL ACCESSORIES
SPEAKERS / PRO AUDIO
ELECTRONIC COMPONENTS
DATA & ELECTRICAL
TOOLS & TEST EQUIPMENT
BATTERIES & MORE!
BUY ONLINE AT
WAGNERONLINE.COM.AU
VISIT OUR SYDNEY STORE
84-90 PARRAMATTA ROAD,
SUMMER HILL, NSW 2130
02 9798 9233

Ian Batty responds: Thank you for pointing this out. Yes, capacitor C4 should come directly from the anode of V1 in both circuits. I have supplied corrected diagrams to SILICON CHIP and the online edition has been updated to correct these errors.

Arduino LC Meter library problem solved

I have built the Arduino-based Digital LC meter from your June 2017 issue (siliconchip.com.au/Article/10676).

I am using an LCD display with the PCF8574AT IC and noted the change on line 21 from 0x27 to 0x3F and have successfully verified and compiled the new version 1.2 firmware and uploaded to the Arduino successfully.

It then started working but the LCD only showed the first character on each line. I was a bit baffled at first but luckily, after doing some web searching, I discovered and fixed the problem. It was a bug in the LiquidCrystal_I2C library. To fix it, in the file LiquidCrystal_I2c.cpp on line 12, change "return 0" to "return 1" as per below:

```
inline size_t LiquidCrystal_I2C::
  write(uint8_t value) {
 send(value, Rs);
 return 1;
}
```

I take no credit for this fix; all I did was to apply it manually. I found multiple forums with people asking the same question and with some responses regarding this solution. Thanks for the project; it works a treat and can't wait to use it.

Tony de la Bere,
Howrah, Tas.

Response: thanks for letting us know; a couple of other constructors reported this same problem and we were a bit baffled since we couldn't reproduce it.

It appears that the bug in the library only occurs on certain versions of the Arduino IDE. We have replaced the software on our website with a version which includes the corrected library code.

Schadenfreude over EA's fall from grace

I wish to convey how much I enjoyed reading the 30th anniversary story (November 2017; siliconchip.com.au/Article/10861), especially the detailed and candid nature in which it was written.

Most interesting was the background story on *Electronics Australia's* demise. Amusing and deserving of the heartiest of congratulations, was the point made about the purchase of EA for much less than the earlier offer when it was a going concern. Again, congratulations on this and all other related achievements.

Brendan Wright,
Golden Square, Vic.

Simpler modem reboot solution is popular

I enjoyed reading the Circuit Notebook entry on page 36 of the September 2017 issue, regarding automatically rebooting the NBN modem (siliconchip.com.au/Article/10785).

My service provider (Optus) has advised me many times during the years to do this procedure.

I studied the circuit and took the lazy way out, using a digital timer to turn my modem off at 3:00am for five minutes every night. I have been doing this from mid-October and speed reduction does not appear now to be a problem over time.

The finer points of design in the circuit (battery backup etc) have been resolved by telling my boys what I have done.

Chris Robertson,
via email.

Instantaneous electric water heaters technology of the 1940s

I read with interest your reply to Mr Goldburg (Mailbag, December 2017). You are indeed correct about the heating using plates immersed in the water to be heated.

But I suspect you may be unaware of the hot water heaters which came into use in the 1940s (or possibly earlier) which used a carbon centre electrode in a metal (possibly cast bronze) body.

These were usually connected across the three phases, subjected to a supply voltage of 415V AC and fused at 30A per phase. I believe they typically drew about 20-25A when operating, the power being between 8-10kW.

They were always mounted high on the wall, with the inlet water feed from a tap below and an unrestricted outlet to shower or bath, so no switching of the power was required as the water would drain out immediately when the tap was turned off, and the current would cease to flow.

For safety, the metal pipework into and out of them needed to be solidly

earthed and the connections to the heater itself was by special non-conductive rubber hoses; it should be noted that the rubber in most hot water hoses contains carbon or other conductive material and in this use will heat up and probably ignite.

These heaters were effectively instantaneous in that they could heat winter-temperature cold water to suitable shower or bath temperatures under normal flow rates – probably, the water would be in the heater for less than a second. Temperature could be controlled by adjusting the flow rate.

There was another type I once came across which was mounted under a kitchen sink, connected in the feed water line prior to the hot water taps and thus would have been permanently filled with water.

It apparently used some type of flow switch to disconnect the power when the taps were turned off. This one was fed with three-phase 415V, fused at 20A in each leg, probably using about 8-10kW. Again, the heating was effectively instantaneous.

www.stiebel.com.au/water-heaters shows a range of single-phase and three-phase heaters which are probably similar to this latter type. siliconchip.com.au/link/aaic compares storage and instantaneous systems.

G. D. Mayman,
Sturt, SA.

Leo Simpson comments: I am old enough to remember those 3-phase instantaneous heaters and how problematic they were, especially if you were having a shower.

If the hot water tap was not turned on quite hard enough, the water would run cold and then if you turned the hot tap on just slightly harder, it ran too ##&# hot! So you had the choice of being frozen or scalded!

Most people were glad to upgrade to an off-peak hot water system which did not have that problem and also had the advantage of a cheaper tariff. In fact, an advertised feature of new houses in those days was an "OPHWS".

Today's instantaneous hot water systems, whether gas or electric, have much better temperature control.

Design of 6GHz+ Frequency Counter praised

I just saw the first part of the new Frequency Counter project in the October 2017 issue (www.siliconchip.com.au/Article/10825). Thanks for a classy project.

I have constructed countless projects over the years but have tapered off in recent times due to many other conflicting interruptions to free time. This one has whetted my appetite and I must admit that I am now waiting on the companion Spectrum Analyser and Digital Storage Oscilloscope to complete the collection. Well done!

Kevin Crockett,
Axedale, Vic.

Superheterodyne principle was developed by multiple people

In the November 2017 issue of SILICON CHIP, on page 52, you cite Edwin Armstrong as inventor of the Superhet principle (patent filed December 1918). He was preceded by Lucien Lévy of the Telegraphie Militaire under Colonel Gustave-Auguste Ferrié (patents filed August 1917 & October 1918) and Walter Schottky (June 1918), among others.

Armstrong would have been familiar with Lévy's work. They were both associated with Ferrié, developing wireless communication in France during the Great War. US courts have agreed that Lévy has precedence over Armstrong. Armstrong could be said to be creator of commercial radio receivers based on the Superhet principle.

The Superhet principle had been used in telephony circuits well before this but was not recognised as such until the above patents appeared.

Peter Hadgraft,
Holland Park, Qld.

Comments on November issue

In the Mailbag section of the November issue, there was mention of charging electric cars at night. I have no doubt that would be a common idea but it doesn't make much sense to me.

If there is no storage of solar energy, then the energy will come from a conventional power station ie, coal, gas or nuclear and to a lesser extent from hydroelectric, wind or geothermal. If it comes from coal or gas, then what is the advantage of electric cars?

On the other hand, if solar energy is stored in large stationary batteries or in pumped storage, that makes even less sense because of the doubling of charging and discharging losses, ie, in the bulk storage and the car's battery.

OCEAN CONTROLS

Helping to put you in Control

LogBox Connect BLE
is abluetooth data logger with 3 universal analogue inputs and a digital I/O. Thermocouples, RTD's, 4-20mA, voltage and pulse output devices can be logged. A smartphone or PC can be used to configure and view logged data .
SKU: NOD-010
Price: $449.95 ea + GST

UniPi Neuron M103 PLC
Based on the popular Raspberry Pi 3 model B the M103 is a universal cntrol unit with 12 DI, 12 DO, 1 AI, 1 AO and a 1 wire interface.
SKU: UPC-005
Price: $424.95 ea + GST

UniPi 1.1 Lite
Industrial grade I/O expansion board for Raspberry Pi 3 B board. Together they form a programmable control unit for universal use in automation, regulation, and monitoring systems.
SKU: RKS-113
Price: $134.95 ea + GST

Motor Driver for Raspberry Pi
Control two high-power DC motors with a Raspberry Pi. Its twin discrete MOSFET H-bridges support a wide 6.5 V to 30 V operating range and are efficient enough to deliver a continuous 22 A without a heat sink.
SKU: POL-3574
Price: $99.95 ea + GST

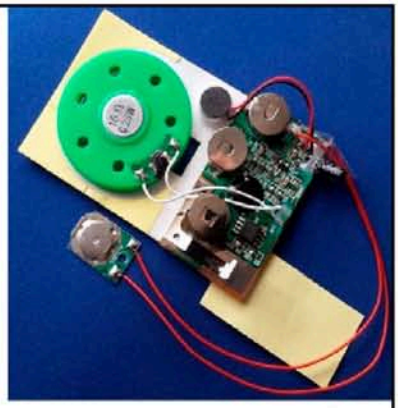
Soil Moisture and Temp Sensor
RK520-01 Combined Soil Moisture & Temperature Sensor and provides 4-20mA out.
SKU: RKS-055
Price: $249.95 ea + GST

LED Programmable Power Supply
Mean Well DRA60-12 can be used in LED driving applications. Output current is adjusted by a 10 vdc, potentiometer or PWM sensor.
SKU: PSM-1640
Price: $45.00 ea + GST

Thermocouple Multiplexer Shield
This shield allows you to connect 8k thermocouples to your Arduino.
SKU: KTA-259K
Price: $49.95 ea + GST

For Wholesale prices
Contact Ocean Controls
Ph: (03) 9782 5882
oceancontrols.com.au
Prices are subjected to change without notice.

Add Sound to your next project with our NEW KSSM-60S



A 60 Second Sound Recording and Playback Module,
complete with batteries, microphone, speaker and playback switch, bringing an added dimension to model construction and craft projects.

HERE ARE A FEW APPLICATION IDEAS

DIY Doorbells - Talking Artworks - Gift and Music Boxes Record a Moment - Add a Message to a Trophy - Add Sounds to Model Railways - Talking or Singing Special Occasion Cakes - Soft Toys – Build into a Model Spooky House or a Tardis- Add Mechanical Sounds to Superhero Outfits – Make Self-Describing Science Fair Displays

Price $7.77 inc. GST Plus Pack and Post

For More Details or to Buy On-line Contact:

KitStop electronics – the fun starts here

www.kitstop.com.au
Email: info@kitstop.com.au
P.O. Box 5422 Clayton Vic.3168
Tel:0432 502 755

The most efficient system would be to charge directly from solar panels during the day but of course, this is when cars are normally needed.

Either the cars must be charged while they are parked (preferably every time they are parked) or they need to be fitted with removable battery packs. The battery packs that are not in use can be charged either privately or commercially during the day.

If the battery packs were modularised to a particular size and voltage, then a motorcycle may take only one. A small car may take two or three and a large car may take four to six.

Spares could be carried if needed and I have no doubt that a standardised battery would find other uses very quickly.

In a previous email to you, I commented on the intention of several European countries to ban cars with internal combustion engines in the future. Since that email, I have thought about it occasionally.

Considering that the largest problem is pollution within cities, one possibility is to use hybrid cars that only operate as electric cars within the city.

All cars would communicate with a control centre within the city and would be commanded to run on electric power as soon as they came within a specified zone. Obviously, there are a lot of "devils in the detail" but none have come to mind which doom the idea.

In the Serviceman's Log column (also in the November issue), Dave Thompson describes a bad experience with LED lights in a range hood. Of course, I failed his question, having assumed that the switchmode power supply was dead. I had assumed that it was a constant voltage supply and not a constant current supply.

My sister had two identical LED flood lights fail and both units used constant-current switchmode supplies. There was no current limiting between the power supplies and LEDs.

In Dave Thompson's case, I suspect that the original supply was either a constant current supply or a constant voltage supply driven into current-limiting mode.

Regardless of the type, the lights probably had no current limiting of their own and consequently, as soon as one light died, the other would be over-driven and it would die as well.

George Ramsay,
Holland Park, Qld.

Updates and fixes for Arduino Music Player project

I am pleased to advise that I got the Arduino Music Player from the July 2017 issue (www.siliconchip.com.au/Article/10722) working. Initially I had problems because I was using a faulty SD card and also a bad jack connector on my headset.

I also noticed that the surface mount pull-up resistor on the SD CS line was badly soldered and there was no continuity to the SD card CS pin due to a very fine break in the printed wiring trace near the resistor.

After fixing the trace and replacing the resistor, everything works great except recording. When in record, the microphone works but there is a loud buzz in one of the channels.

I found a lot of ripple on the audio output and also the 3.3V supply line. Checking the voltage of the 3.3V with a DVM, it measured 4.2 volts, a little high don't you think? Maybe the problem is with the regulator.

After recording audio, I notice on playback that there are loud glitches now and then and samples are dropped every couple of seconds.

As an example making a recording counting from 1-20 then on playback, a numeral would be missing now and then. Playback works fine with MP3 and Ogg recordings which were downloaded to the SD card off the web. I have also found the following problems with the software:

1. When using the "*" button to stop playback or recording, the system locks up.

2. Selecting a particular playback track entering a track number of a known recording always returns a "no such track" message on the LCD.

3. When selecting record the LCD displays "recording..." and nothing else appears while the recording is made.

4. Most times, instead of making a new file on new recordings, it just overwrites the previous recording.

My Arduino IDE version is 1.8.3. I am using a Futurlec 4x4 keypad, checked with continuity meter for correct connections and a Samsung 32 GB microSDHC UHS-1 card. I am using Windows 7.

No hardware changes or additions have been made to the board assemblies. The software and the plugin/patches are from SILICON CHIP download package.

Maybe somewhere I'm doing something wrong. I am wondering if I have a board that does not tolerate very well to the +5V Arduino signals applied to the max 3.6V

on all pins of the VS1053. As you mentioned in your article, Sparkfun used a 74HC4050 level shifter to deal with these voltage differences.

I would appreciate your comments regarding these faults.

Richard McEwan,
via email.

Response: we explained why the 3.3V rail normally measures around 4.2V in the middle column on page 73 of the July 2017. The ripple due to this "supply pumping" could be the cause of the buzzing noise you have in your recordings.

We suggest you try soldering a 3.6V zener diode across the 3.3V rail (anode to ground) to prevent the supply being pumped up.

Bao Smith has spent some time looking into the other problems you reported and has solved them and a few other issues in the updated version (1.2) of the software which is now available for download from our website. Regarding the software problems, he reports:

***1.** The "*" button causing a lockup was due to that row of the keypad being connected to digital pin 10 (SS). This is not wired up to anything on the VS1053b shield but the SS function is part of the SPI interface.*

Unfortunately, the ATmega chip does not support using the SPI interface without using this pin, even if you don't need it and this was interfering with the keypad operation.

The software has been changed to use the D0 (RX) pin for this function instead and it no longer locks up. Note though that because this pin is used for the USB/serial console, pressing a key on the bottom row of the keypad will cause garbage data to be transmitted over the serial console.

However, this does not interfere with the program's operation. There are no other suitable free pins to use for this function.

***2.** The "no such track" error message seems to occur if you try to play a file immediately after terminating playback/recording and is due to the SD card library not freeing the file in a timely manner. Wait a few seconds and try again and it should work. The ability to select between MP3 and Ogg formats when playing a track has also been added.*

***3.** A timer has been added to show how many seconds the unit has been recording.*

***4.** By default, the program records to a file called "recordXX.ogg", where XX was a number from 01 to 99 and increases each time you record. Now the recording starts from 00 and you are given the choice to input a value from 00 to 99 when recording; pressing "A" on the keypad will use the old increment method.*

Regarding the drop-outs you have noticed during recording, version 1.1 has been altered to write the Ogg file in 256-byte blocks instead of individually writing each byte.

We initially chose to write one byte at a time because memory restrictions prevented us writing a 512-byte block in one go. We believe the larger block writes will solve the drop-outs.

If they don't, refer to the VS10XX datasheet titled "VorbisEncoder170c.pdf" under Section 2, Page 5. It lists five different "profile groups" for recording. We've used the default "Stereo Music" profile which records at 44.1kHz.

You could modify the software to use one of the other, low bit rate profiles, in case your SD card can't keep up with the data rate (which seems unlikely, based on the information you have given us).

*There is some extra relevant information under the "Performance" heading here: **siliconchip.com.au/link/aaid** and on the vsdsp forum: **siliconchip.com.au/link/aaie***

Note: Richard wrote back to tell us that the zener diode did indeed stabilise the supply rail and solved the buzzing problem. The software changes also fixed his issue with the dropout occurring during recording.

The updated software also fixed an issue when recording and then playing back FLAC files (or music files that needed the additional plugin before they could be loaded) that would cause the player to freeze.

This was fixed by resetting the player after a recording had been attempted.

Using digital wireless protocols for model railway

We have seen rapid and far ranging developments in nearly all consumer electronics over the last 10 years but model train control seems to be stuck using 30+ year old technology. Yes, I know and use digital command control (DCC) and some fantastic sound modules. But DCC is based on 30+ year old technology. The components have been updated but its operating principle is still ancient.

When DCC first came along, the NMRA and major manufacturers agreed on a standard and have stuck to this ever since, which I believe has stifled any new developments. The plus side is that most of the DCC equipment was compatible between all brands.

DCC uses digital signals superimposed onto the power supply fed to the rails and each locomotive has a decoder which interprets this signal to control the train, direction, speed and auxiliary channels such as lights and sound. This square wave on the track is rectified and also used to power all the functions of the locomotive.

This means that the master controller has to be able to supply 5A (most locos take almost 1A, some a lot more) and much more for larger layouts (more trains). This makes it expensive.

There are a few alternatives starting to appear but none have really taken off mainly because the decoders are too large for a lot of locos unless they have been designed to fit them.

These use Bluetooth or WiFi as its means of control and almost any DC or AC power source is suitable for feeding the rails. Your old smart phone or tablet becomes a portable controller. So the major cost now disappears.

I would like to see a new system which uses Bluetooth and works on Apple and Android phones with a combined Bluetooth transmitter/receiver and decoder, similar in size to existing DCC decoders or a small Bluetooth transceiver for direct connection to existing DCC decoders.

It would also have the option for locos to have an internal battery that's charged by certain sections of the track. That would make reverse loops so much easier to use.

Have a look at Bluerail trains and also Bachmann E-Z .These look promising and have announced future upgrades to their existing models. Could SILICON CHIP come up with something similar?

Martyn Davison,
Paynesville, Vic.

Leo Simpson responds: This is a most interesting suggestion, although I am not sure that WiFi or Bluetooth would be able to provide the number of channels that would be required to control all the locos and peripherals on a typical layout. SC

Monitoring our world – and beyond – with *tiny* satellites

Swarms of miniature satellites – some so small you can fit them in the palm of your hand – are watching us from way out in space. They take *millions* of pictures every day, beaming images down to Earth to enable changes on our planet surface to be monitored in minute detail. And one of the main factors providing the capabilities these tiny satellites is the incredible progress in smart phone technology. In effect, smart phone bits are watching us from up there!

by Dr David Maddison

While you may not have realised it, a modern "smart" mobile phone has nearly all the components you need in an Earth-imaging satellite.

Relatively inexpensive, it has a high performance processor, a large amount of memory, cameras, accelerometers, gyroscope, 3-axis Hall Effect magnetometer, GPS and GLONASS, a built-in battery and rugged construction.

Assuming its components will stand up to radiation, a vacuum and temperatures between about -40°C and +80°C, the only extra components needed are an external power supply to keep the battery charged and a means to send data back to Earth (smart phone signals won't work from space and no, ET can't phone home!)

Another advantage of a smart phone is an open source operating system such as Android which enables custom software to be written to control the device.

If the electronics of the smart phone were to be built from scratch, for a boutique application it would be an extremely expensive exercise.

But the development of phones is funded by billions of terrestrial users – you and I – which is why these devices are so affordable.

In 2011 NASA developed PhoneSat 1.0, with a CubeSat form factor but actually based on the Nexus One smart phone, using the Android operating system. It used an external Arduino processor as a "watchdog" to monitor the phone and reboot it, in case it suffered a software crash.

The purpose of this exercise was to demonstrate the concept and to prove that the phone could survive in space and send back its own status and picture data.

NASA launched some additional PhoneSats and in 2014 launched PhoneSat 2.5 with a mass of about 1kg. The PhoneSat 2 series is based around a Nexus S-series phone. The mission objective was to test longer term missions in the higher radiation environment of space to use smartphone technology to control attitude control, data handling and communications.

PhoneSat 2.5 used reaction wheels for attitude control (see panel). It had a two way S-band radio (2 - 4GHz) with a high gain antenna so it could be controlled from Earth. PhoneSat 2.5 remained in orbit from 18 April until 15 May 2014.

Oil tanks usually have floating tops, so called "external floating roof tanks" so by imaging these tanks and analysing their shadows it is possible to infer, for example, how much oil a country is exporting or about to export. The daily imagery provided by Planet allows a daily update of oil data that can be used by people working in the crude oil market.

Downlink data was received by radio amateurs around the world and sent to NASA.

From tiny satellites . . . to teeny ones!

Satellite sizes are normally classified by mass. At the lower end of the size range, femtosatellites are between 10 and 100g, picosatellites are 100g to 1kg, nanosatellites are 1 to 10kg, microsatellites are 10 to 100kg and small satellites are 100 to 500kg. Of these categories the nano and micro size satellites segments are growing the most rapidly.

CubeSats (see siliconchip.com.au/Series/281) which are based on one or more 10 x 10 x 10cm standard units are

Deployment in 2016 of two of the final eight of Planet Lab's Flock 2e' Doves from the International Space Station. The life-time of these tiny satellites is about one year if launched from the ISS in a 420km altitude orbit inclined at 52°.

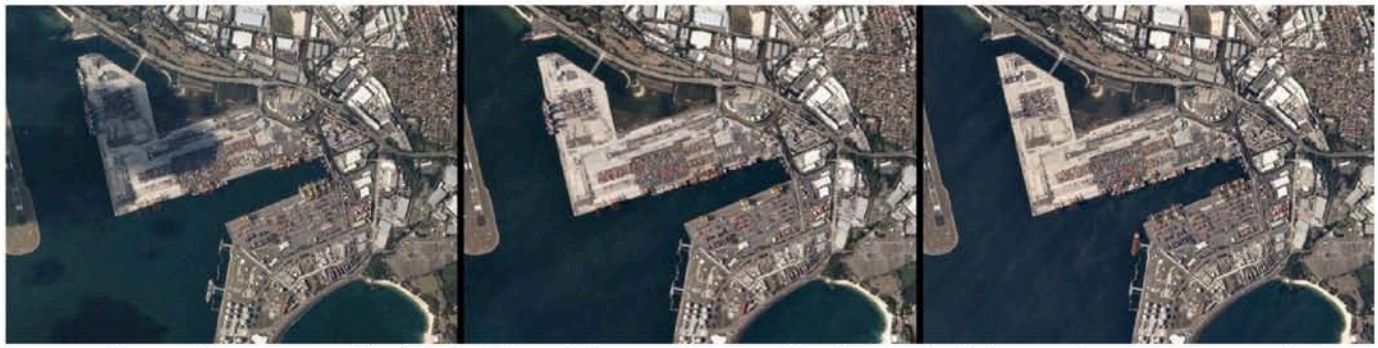
NanoRacks CubeSat Deployer

CubeSats are normally launched as opportunistic payloads attached to other satellite launch platforms but once in space they still have to be somehow ejected away from the main spacecraft. This is normally done by a deployment module which contains a spring which pushes the satellite away.

One device designed to do this, shown on page 19, is the **CubeSat Deployer** made by a company called NanoRacks. It is intended to launch CubeSats from the International Space Station (ISS) where they have been taken as part of a normal cargo delivery.

Each Deployer can hold one 6U CubeSat or six 1U or a combination of different sizes that add up to 6U. Eight 6U modules can be deployed per ISS airlock cycle, so theoretically up to 48 1U satellites could be launched.

Corporate video showing CubeSats being deployed from the ISS: *"NanoRacks CubeSat Deployer (NRCSD) on the ISS"* https://youtu.be/AdtiVFwIXdw



Images taken on three consecutive days by Planet Labs satellites over Port Botany in Sydney on January 21, 22 and 23 last year showing ship and cargo movements. Automated software can be used to track shipping movements in and out of port.

classified as nanosatellites.

The cost of launching a satellite is mostly proportional to its weight and volume so the lighter and more compact the satellite is, lower the launch cost.

Huge numbers of small size satellites have now been launched and in this article we will look at just a few types that are being used to conduct Earth imaging and other forms of monitoring.

Videos: *"Android Phone as Autonomous Micro-Satellite: PhoneSat"* **https://youtu.be/uXDPhkbTHpU** and *"PhoneSat Mosaic of Earth"* **https://youtu.be/dzs2wc2JEWw**

For more information on a variety of PhoneSats see **http://phonesat.org/**

Planet Labs

Planet Labs, Inc (**www.planet.com/**) is producing small size satellites for Earth imaging with an objective of daily updates.

This is quite unlike Google Earth which is updated infrequently, on average every 1 to 3 years. Compared to Google Earth though, the imagery from Planet Labs is at a lower resolution, of around 3 to 5 metres, while Google has a resolution of between 15cm and 15 metres, depending upon which platform was used to do the imaging.

The advantages of Planet Labs imagery are its relatively low cost and the regular updates.

Planet refers to individual satellites as Doves and the satellite constellation (group of satellites) as a Flock. Planet mainly uses off-the-shelf components in its satellites.

With the exception of five special satellites (RapidEye), most of the satellites themselves are built on a standard CubeSat platform of 3U (3 unit) size, making them nominally 10cm square and 30cm in length before solar panels and antennas are unfolded and with an extra 4cm of length (to make a total of 34cm), as allowed within the CubeSat specification. The CubeSats weigh around 5kg each.

Planet satellites not based on the CubeSat model are the RapidEye models which they acquired when they took over another company.

RapidEye models are a more conventional design based upon the SSTL-100 spacecraft bus (the standard basic structural frame, propulsion unit and communications that can be used for a variety of spacecraft models).

These satellites are about one cubic metre in volume and weigh about 150kg so are categorised as "small satellites" but we will focus primarily on the Planet CubeSats.

The first Planet CubeSats, Doves 1 through 4, were launched in 2013 as demonstrators. Flock 1, consisting of 28 Doves, was launched in February 2014 from the International Space Station (ISS) in a short-lived orbit of 400km altitude.

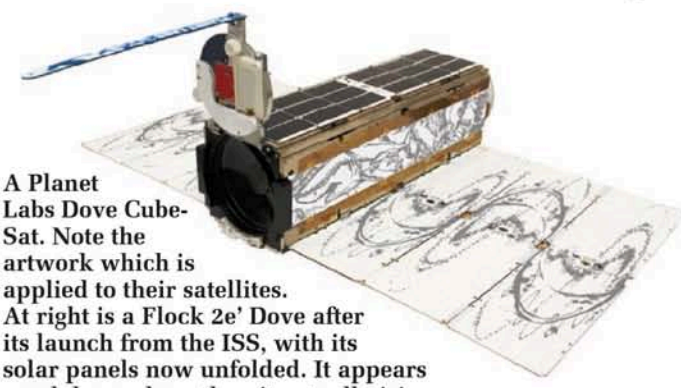
Since then a number of additional Flocks have been launched comprising Flocks 1b, 1c, 1d, 1d', 1e, 1f, 2b, 2e, 2e', 2p and in February 2017, Flock 3p.

Planet looks for the cheapest launch platform available on which to piggyback its satellites. There have been two launch losses so far: 26 satellites were lost with the launch failure of Flock 1d and eight were lost with Flock 1f.

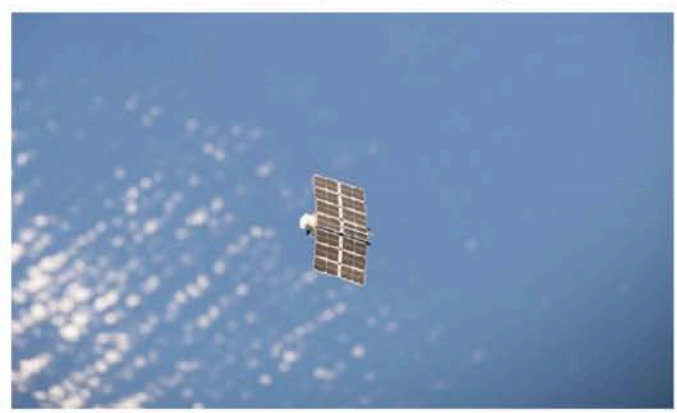
The orbit life-time of these satellites is about one year if launched from the ISS in a 420km altitude orbit inclined at 52°, or two to three years if launched from a rocket in a sun synchronous orbit (SSO), which is a polar orbit of 475km inclined at 98°.

Planet aims to have up to 55 satellites in ISS orbit and 100-150 in SSO. In ISS orbit the equator crossing time is variable and in SSO it occurs between 9:30-11:30AM local solar time.

The communication frequencies used by the Doves are



A Planet Labs Dove CubeSat. Note the artwork which is applied to their satellites. At right is a Flock 2e' Dove after its launch from the ISS, with its solar panels now unfolded. It appears much larger here than it actually is!



Perhaps even more dramatic, these images from Planet Labs satellites show the "development" of illegal gold mining in a protected area of Peru – the left photo on 29 January 2016 and the right on 4 November 2016. The Amazon Conservation Association used this imagery to issue alerts about this activity and the Peruvian Government intervened to stop it.

X-band: 8025-8400MHz for downlink and 2025-2110MHz for uplink with additional backup frequencies. Ground stations are located in the US, UK, NZ, Germany and Australia and utilise a 5m dish antenna.

There are three generations of Dove optical sensors, the earliest being 11MP resolution and the latest being 29MP.

The most recent launch of Planet CubeSats was the successful deployment, on 31 October, of six SkySats and four Doves (flock 3m) on Orbital-ATK Minotaur-C rocket.

After this launch there were 160+ Doves and 4 Planet satellites in orbit, enabling the fulfilment of the objective of being able to image the entire Earth's surface every day.

This launch constituted the largest number of satellites launched on one rocket and the constellation of 149 satellites is also the world's largest privately-owned constellation.

Each of the Flock 3p satellites has a 200Mbps data downlink and produces two million square kilometres (a little more than the area of Queensland) of imagery per day.

See video *"Mission 1: A Record-Breaking Launch"* **https://youtu.be/6VuDsCfuoM8**

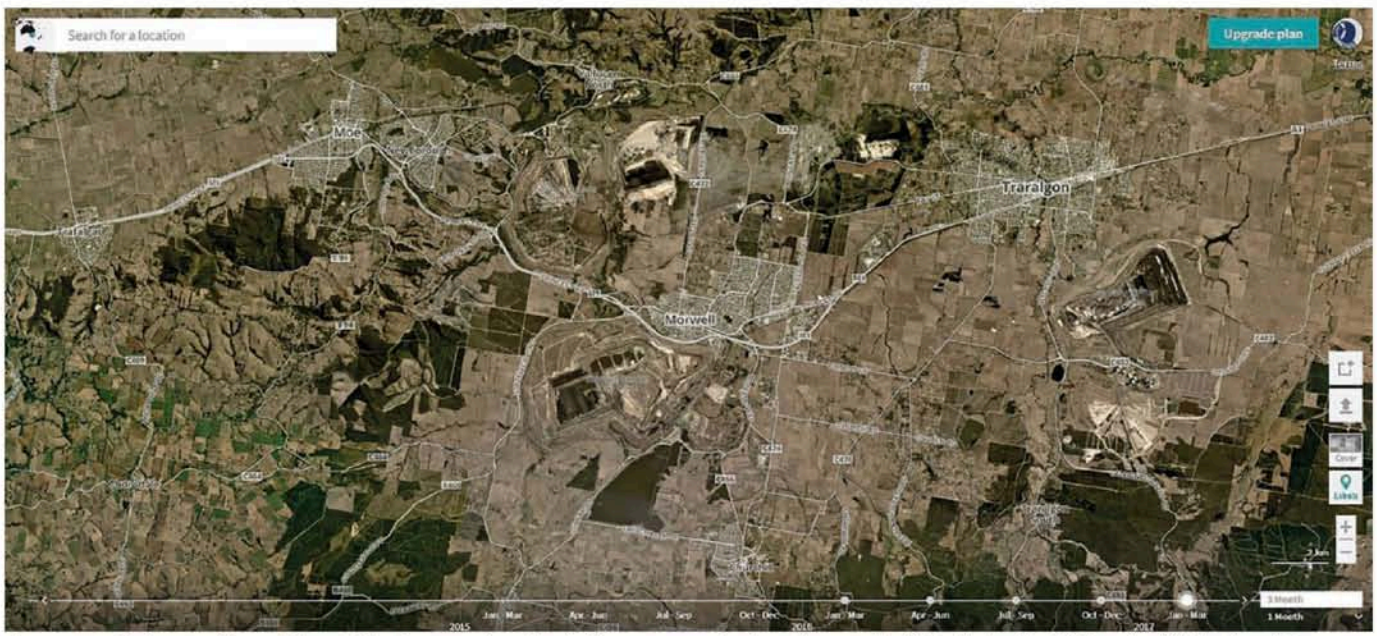
Sailing in the upper atmosphere

Once released from their launch vehicle, Planet's satellites navigate to their desired positions in an unusual way. Even at orbital altitudes there are minute traces of atmosphere so the solar panels are used as "sails" to navigate to the desired position.

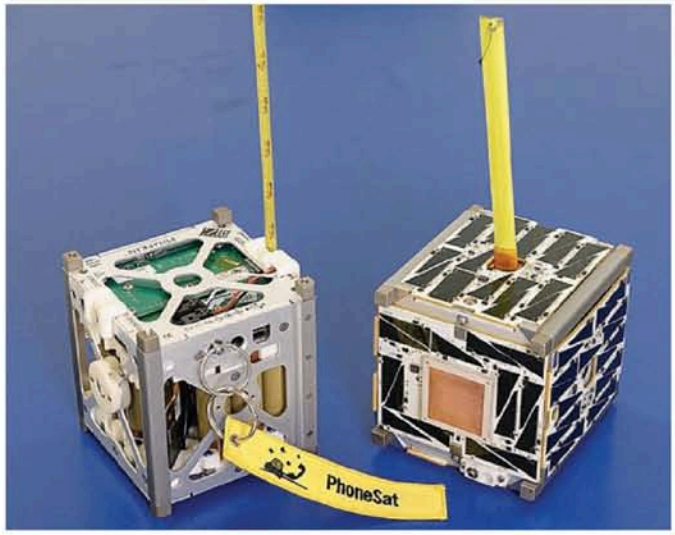
When they are at right angles to the orbital track they offer seven times more "wind resistance" than when they are edge on.

Tilting the solar panels is used to manoeuvre the satellites into the desired position by increasing or decreasing the drag caused by the panels.

Once in the correct position the satellites need to be oriented correctly and use magnetorquers and reaction



An example image from Planet Explorer using their free account, showing part of the Latrobe Valley in Victoria with several coal mines and the recently-closed Hazelwood Power Station (barely visible) just south of Morwell. Note the the timeline along the bottom of the image, you can drag the cursor along this to see how the landscape changes with time. Higher resolution is available with a paid account.



NASA's PhoneSat 1.0 and PhoneSat 2.5. PhoneSat 2.5 has solar cells on its surface. The satellites are based upon a 1U CubeSat form factor (10 x 10 x 10cm). The antenna really *is* a piece of metal tape measure... and why not?

wheels. (See the separate panels for more information on these devices).

Planet's imagery has a wide variety of uses, mainly involved with observing changes in areas of interest with time.

As examples, one can look at the development of mines, changes in forestry due to logging, ship movements in and out of port, changes in the urban environment and monitor crop growth and health.

You can set up a free account with Planet to explore your own areas of interest, although the imagery available will be at a lower resolution than a paid account. It could be good for school projects, especially watching changes in the landscape throughout the year. Some user stories can be read at **https://medium.com/planet-stories**

Spire's Lemur-2 3U CubSat for monitoring shipping movements and weather.

Video: *"Tiny satellites that photograph the entire planet, every day | Will Marshall"* **https://youtu.be/UHkEbemburs**

Spire Global, Inc.

Spire (**https://spire.com/**) is a company that has a number of CubeSats and describes its business as "space to cloud data and analytics".

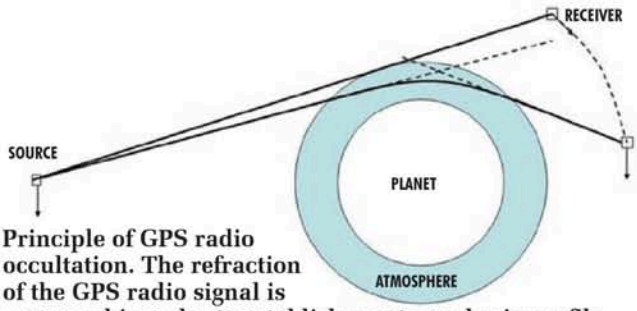
In addition to acquiring data from its own constellation of satellites, it also offers data analysis services. It specialises in data for ship tracking, weather, aviation (in the near future) and custom data acquisition.

Spire originally started out to create the crowd-funded Arduino-controlled ArduSat CubeSat on which people could do their own experiments.

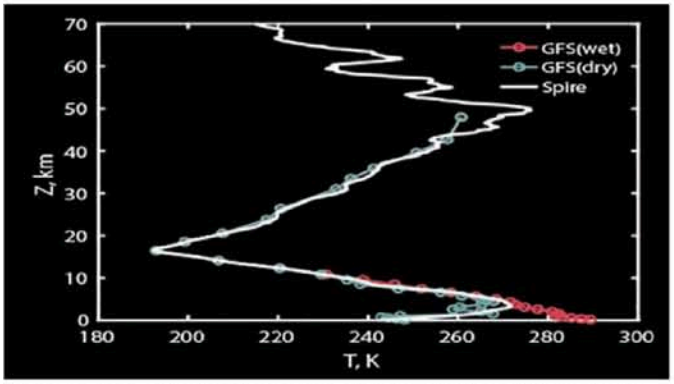
Spire currently uses their 3U CubeSat Lemur-2 satellite for ship tracking and weather observation. It carries as a payload both STRATOS (GPS radio occultation payload) for weather monitoring and SENSE (AIS payload) for monitoring ship movements.

(In GPS radio occultation, a low-Earth-orbit satellite receives a signal from a GPS satellite, which has to pass

Spire uses its constellation of at least 40 CubeSats to monitor world-wide ship movements by monitoring signals from the Automatic Identification Systems (AIS) of boats and ships. AIS automatically transmits a vessel's identity, position, course and speed. When it was originally developed in the 1990s AIS was intended for surface use only and was not intended to be or thought to be trackable from space. There are significant issues related to receiving the signals from space, partly due to the Time Division Multiple Access (TDMA) nature of the AIS signal, which utilises 4500 data slots per minute. Due to the large view of the surface the satellite has, it might be overwhelmed by more signals than this. The problem is resolved by Spire by undertaking extensive data analysis to extract the desired information.



Principle of GPS radio occultation. The refraction of the GPS radio signal is measured in order to establish an atmospheric profile. ***Image author: MPRennie.***



Comparison of actual measured data obtained from Spire and that from the Global Forecast System (GFS) numerical weather model showing a high degree of correlation.

through the atmosphere and gets refracted along the way. The magnitude of the refraction depends on the temperature and water vapour concentration in the atmosphere).

Monitoring ship movements with AIS

To monitor shipping, Spire's constellation listens to the Automatic Identification System (AIS) of over 75,000 maritime vessels on the ocean at any given time and enters them into their database. Over 28 million AIS messages are intercepted each day.

The information can be used by shipping companies to keep track of their ships and make sure they don't enter areas they are not meant to go or determine if they will arrive in port on time.

Other customers can also gain access to the location and probable destination of any of over 300,000 ships in the database.

The likely destination of any given ship is determined by machine learning algorithms based on the history of the particular ship of interest and this information is valuable to competing shipping companies.

SILICON CHIP has featured two articles on AIS, in August 2009 (www.siliconchip.com.au/Article/1528) and January 2010 (www.siliconchip.com.au/Article/41).

When it was originally developed in the 1990s, AIS was intended for surface use only and was not intended to be, nor thought to be, trackable from space.

In fact, there are significant issues related to receiving the signals from space. This is partly due to the Time Division Multiple Access (TDMA) nature of the AIS signal

GPS limitations in space

A common complaint about developers of small size satellites is the regulatory environment with respect to the sale of GPS receivers. There are restrictions to civilian GPS receivers under the Wassenaar Arrangement to prevent the proliferation of technologies with dual military and civilian use.

Since GPS can be used to guide an ICBM to within a few metres of its target, there are restrictions imposed on GPS manufacturers on the maximum altitude and speed at which they can operate before the GPS ceases operation. The limits are set at 18,000m altitude and 1,900km/h. These restrictions are also a frustration for high altitude balloon and model rocket operators.

Unrestricted GPS receivers are available but under great bureaucratic frustration and regulatory controls. Most space-qualified GPS receivers are quite expensive (thousands of dollars) but we have noted a Venus838FLPx-L GPS module, as commonly used in phones, for sale with customised firmware suitable for space applications (unrestricted speed and altitude) for US$99.

NanoRacks CubeSat Deployer

CubeSats are normally launched as opportunistic payloads attached to other satellite launch platforms but once in space they still have to be somehow ejected away from the main spacecraft.

This is normally done by a deployment module which contains a spring which pushes the satellite away.

One device to do this is made by a company called NanoRacks and is called the CubeSat Deployer. It is designed to launch CubeSats from the International Space Station (ISS) where they have been taken as part of a normal cargo delivery.

Each Deployer can hold one 6U CubeSat or six 1U or a combination of different sizes that add up to 6U. Eight 6U modules can be deployed per ISS airlock cycle so theoretically up to 48 1U satellites could be launched.

Corporate video showing CubeSats being deployed from the ISS: *"NanoRacks CubeSat Deployer (NRCSD) on the ISS"* https://youtu.be/AdtiVFwIXdw

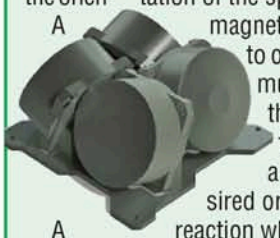
Loading a CubeSat for launch from the ISS into a NanoRacks Deployer.

Orienting and propelling a small satellite in space

Most satellites need to have a particular orientation in space so that their sensors and solar panels panels point in the right direction.

Unlike full size satellites which might be as large as a bus, small satellites such as CubeSats are generally not permitted to carry chemical propellants as they are usually opportunistic payloads on launches of of larger satellites and the mission safety cannot be compromised. Orienting the satellite in space is known as attitude control.

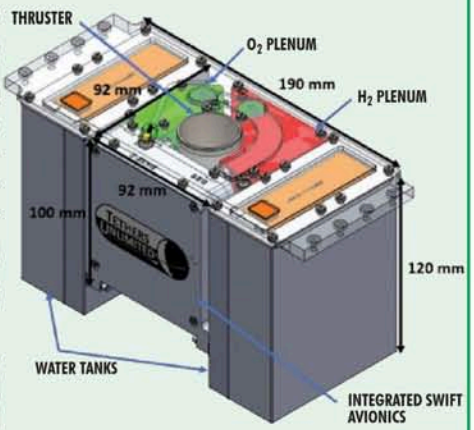
Rare earth magnets are the simplest way to orient a spacecraft. They align themselves with the Earth's magnetic field lines like a compass needle thus giving a predictable orientation although the orientation of the spacecraft varies throughout the orbit.



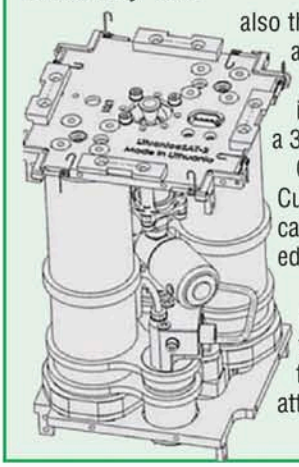
A magnetorquer is a system of electromagnets to orient a spacecraft in orbit. It functions much like a magnet but the power to the coils of the electromagnets can be turned on and off in association with a feedback system to achieve the desired orientation.

A reaction wheel or momentum wheel is a system of motorised flywheels that allow a spacecraft to be oriented by applying a torque to a flywheel. The spacecraft and the wheel will rotate in opposite directions. The flywheel is stopped when the desired orientation is reached.

While propellants are generally not permitted, one innovative idea is to use water as a fuel. Water is launched with the satellite and then electricity from solar panels is used to electrolyse the water into hydrogen and oxygen which together form a rocket fuel.

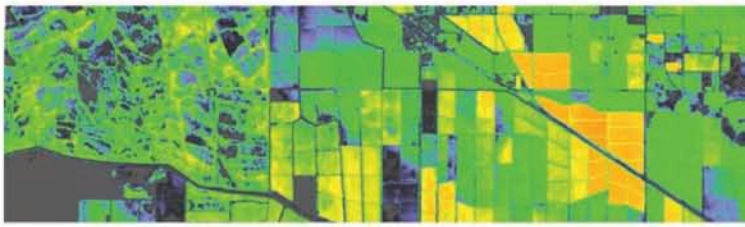


Rodrigo Zeledon at Cornell University and also the company Tethers Unlimited Inc. are both developing water propulsion. Using this propulsion system it should be possible to accelerate a 3U CubeSat to 1-2km per second.



Other thrusters that can be used on CubeSats use compressed gas which can be ejected cold or electrically heated to provide greater thrust.

It is sometimes necessary to have more than one attitude control system on a spacecraft to compensate for various disadvantages different attitude controls systems may have.



Astro Digital image of California farmland processed using the NDVI (normalised difference vegetation index) calculation.

which creates 4500 data slots per minute but because of the large view of the surface the satellite has it might be overwhelmed by more signals than this.

Spire has resolved this problem by extensive data analysis to extract the desired information.

Monitoring the weather

To monitor the weather Spire uses GPS radio occultation to derive the temperature, pressure and water vapour content of the atmosphere.

It observes the degree of bending (refraction) of the signal and time delay of a GPS that is low on the horizon compared to an observing satellite.

The refraction is too small to observe directly but can be inferred by measuring the Doppler shift of the signal for a given geometry of the transmitter and receiver.

Videos: *"Small Satellites With a Huge Impact"* **https://youtu.be/aQb-XacYQvw**, *"Why Spire Uses Satellites To Listen To Earth's Oceans | Forbes"* **https://youtu.be/JHdu-JEvWrN8** and *"Peter Platzer talks about trying to revolutionise weather forecasting, one satellite at a time"* **https://youtu.be/M_x-Jvk4lqc**

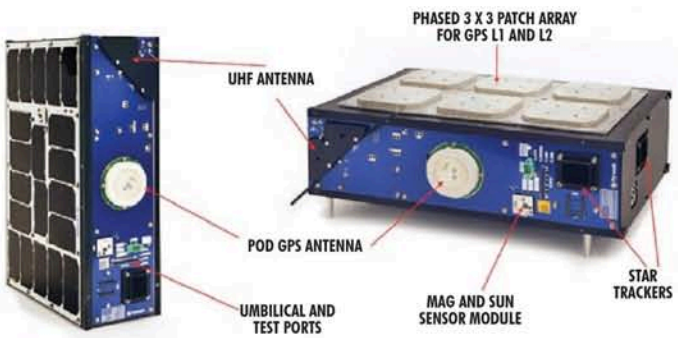
GeoOptics

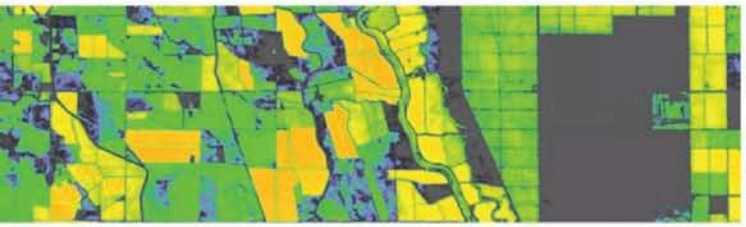
GeoOptics, Inc. (**www.geooptics.com/**) will also be using GPS radio occultation techniques to provide weather data. (In fact, it is also possible to use other global navigation systems such as the European Galileo and the Russian GLONASS.)

They are in the process of installing a constellation of satellites made by Tyvak, Inc (**www.tyvak.com/**) that are a double-wide 6U CubeSat form factor, meaning dimensions of 60 x 20 x 10cm.

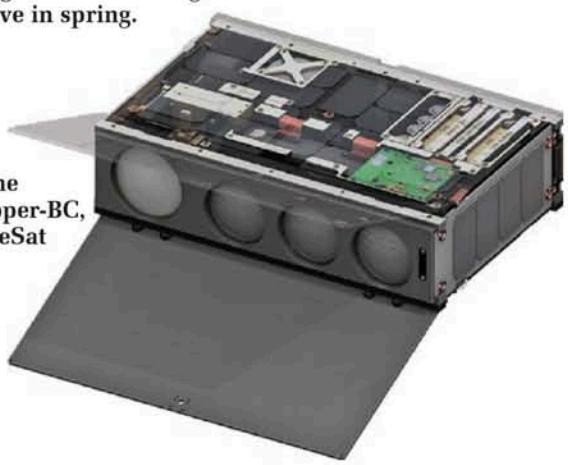
Its satellites weigh around 10kg and produce an average of 21W from their solar panels. They use magnetorquers and reaction wheels for attitude control and star trackers to determine attitude.

They named the satellite CICERO or Community Initiative for Cellular Earth Remote Observation. It will eventu-





NDVI show areas with the highest amount of vegetation in the brightest colours Vegetation in California is the most active in spring.



Cutaway view of the Landmapper-BC, a 6U CubeSat with 3U side-by-side.

ally form a constellation of 24 or more satellites.

In addition to using GPS radio occultation techniques CICERO will also observe signals reflected off the ocean (reflectometry) to determine ocean temperatures and wind speeds.

Landmapper

Astro Digital US, Inc (https://astrodigital.com/) has a 30-satellite constellation comprising 20 16U CubeSat 20kg Landmapper-HD satellites and 10 6U CubeSat 10kg Landmapper-BC satellites.

The Landmapper-HD constellation images all agricultural land on Earth every 3-4 days at a resolution of 2.5 metres and it orbits at an altitude of 650km. Its largest component is its telescope. It has a camera that consists of a 5-band spectral imager taking pictures in the blue, green, red, red edge and near infrared parts of the spectrum which are assembled into individual images of about 450 square km.

The spectrum bands used match that of Landsat so historical images can be compared. This constellation generates 15TB of data per day and 25 million square km are im-

A cutaway view of the Landmapper-HD satellite. Most of the lower portion of the satellite is the telescope. This is large for a CubeSat, at 16U size.

Thumbsat

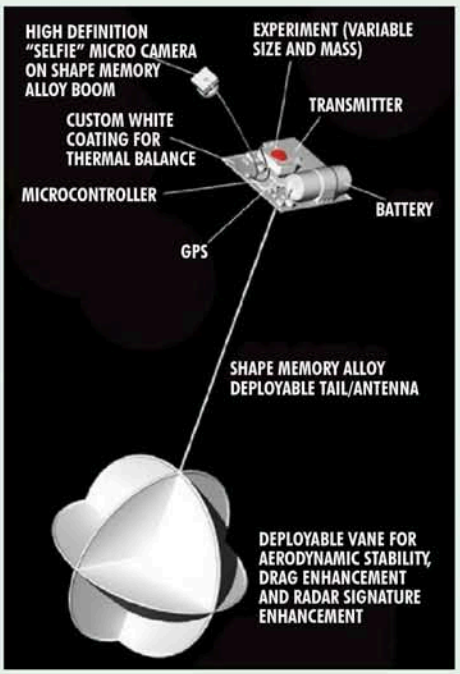
Circuit board of ThumbSat shown without the "vane" or the camera. The satellite will fly as a bare circuit board without an enclosure.

Thumbsat (www.thumbsat.com/) is a femtosatellite (10-100g) platform, designed for researchers to get their experiments into orbit for around US$20,000.

It coexists with a companion project, Thumbnet, which is a network of amateur trackers using software-controlled radios with automatic antenna pointers to receive the data and upload it via the Internet.

These devices have not yet been launched but like KickSat, show the potential for even larger and cheaper technologies for Earth surveillance.

As of July 2017, there is an agreement with CubeCab to launch 1,000 ThumbSats on its launch vehicles.



Thumbsat in one possible configuration. To the left is a vane to provide some drag in the extremely thin traces of atmosphere and therefore stability in orbit and also to increase visibility to radar. To the lower right is a camera of 1048 x 1536 pixels which can be fitted with a variety of lenses. On the main board there is a 100mW transmitter operating in the 400MHz band, a battery and power supply, a microcontroller, a GPS receiver and in the centre with the red marking is the customer experimental payload which can be up to 48 x 48mm per side and 15 to 32mm thick with a mass of up to 25g. Note the scale at top left.

Build your own CubeSat

The are many opportunities to build your own CubeSat or other small-size satellites and this can be done relatively inexpensively – although launching it is by far the biggest cost and you will likely have to share the cost with others or crowdfund your project.

The PhoneSat, developed by NASA, is a CubeSat that easily fits into one hand!

CubeSat is by far the most popular format for projects of this nature. In Australia there are CubeSat groups in Sydney, Melbourne and Perth. You can find resources at www.cubesat.org/

Two examples of the many companies selling off-the-shelf components for CubeSats is at www.cubesatshop.com/products/ and at www.cubesatkit.com/

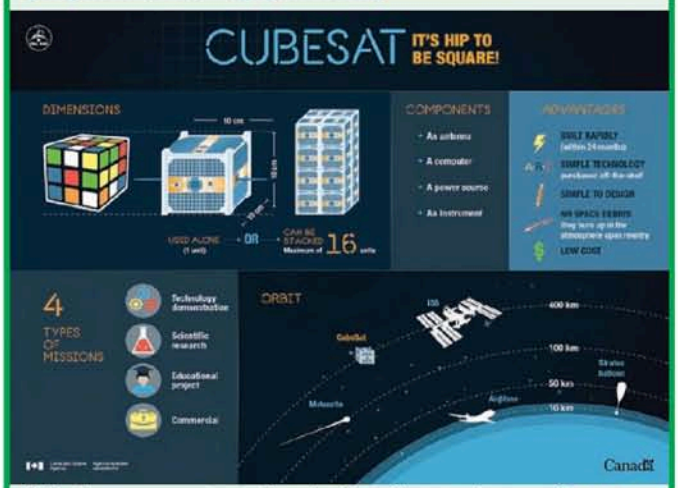
An Australian company, Freetronics, sells Arduino controllers for CubeSats (www.freetronics.com.au/collections/ardusat). Johnathan Oxer, the owner of Freetronics, talks about Arduinos in space in this video: *"Deploying software updates to ArduSat in orbit - Jonathan Oxer - Friday Keynote - Linux.conf.au 2014"* https://youtu.be/0GHMTXiDqoA

EEVBlog talks to Jonathan Oxer *"EEVblog #519 - Ardusat Arduino Based CubeSat Satellite"* https://youtu.be/WCfG0OBEPHM

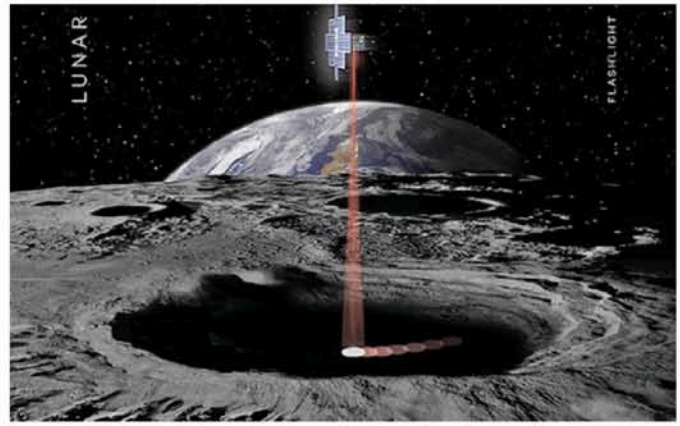
Preliminary testing to test the concept of using a smart phone as a phone sat by launching it on a rocket is shown here: *"PhoneSat Rocket Launch Documentary"* https://youtu.be/nSyWDqgNRmo and *"NexusOne/Arduino PhoneSat Satellite Launch Video"* https://youtu.be/hQ7pUroGvFc

Some basic information on building your own satellite and some links to other articles: https://makezine.com/2014/04/11/your-own-satellite-7-things-to-know-before-you-go/

A project that does not appear to be active but was about making high resolution imagery of the earth with CubeSats contains some useful calculations in various areas, especially for those doing imagery and a discussion of the constraints: https://sites.google.com/site/fiveguyscubesats/



This image, courtesy Candadian Space Agency, (www.asc-csa.gc.ca) shows the basic "rules" of a CubeSat. There's a wealth of information on the 'net if you want to build your own – and get it into space!



Lunar Flashlight, a mission planned for November this year, will detect water ice (especially in the shadows of craters) but in addition will look for other other volatile compounds and will use a near infrared laser and a spectrometer to detect these materials. It will be the first time a laser has been used to detect ice beyond Earth.

aged daily with a swath width of 25km.

The Landmapper-BC constellation satellites complement the data from Landmapper-HD and produce images of 22-metre resolution with an area of 30,000 square km. It takes images in the red, green and near infrared parts of the spectrum. Like the HD it orbits at an altitude of 650km. All of the globe is imaged daily with this lower resolution constellation, generating 1.2TB of data per day per satellite and 150 million square km are imaged per day with a swath width of 220km.

Both satellites are in a Sun-synchronous orbit (SSO) which means they cross the equator at the same time each day. Orbit lifetime is five years for both constellations.

Some examples of imagery can be viewed at https://astrodigital.com/gallery/#aral-sea As with Planet, you can sign up for free for a limited access account to view imagery or pay for a less restricted account.

IceCubes to the Moon

Lunar IceCube and Lunar Flashlight are two planned NASA missions to send 6U CubeSats to the moon.

IceCube is planned for 2019, to determine the location and extent of ice deposits on the moon. IceCube weighs 14kg and will employ a spectrometer to detect ice and a tiny RF ion engine using iodine as the propellant and generating 1.1mN of thrust (0.1g of force) from a 50W power input, for manoeuvring.

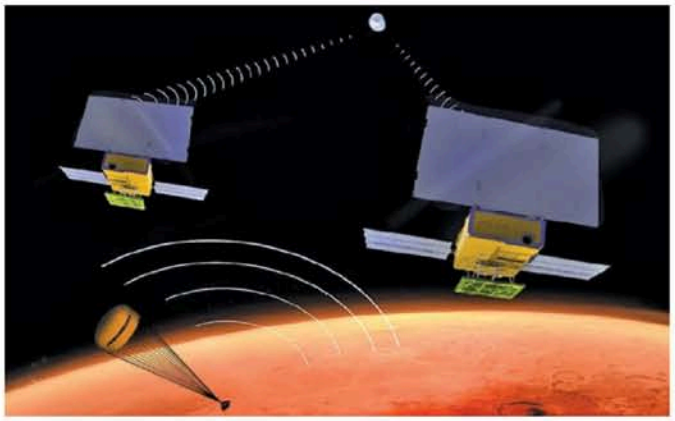
Lunar Flashlight, planned for launch in November this year, will also detect water ice (especially in the shadows of craters) but will also look for other volatile substances with a near-infrared laser and a spectrometer. This will be the first time a laser has been used to detect ice beyond Earth.

CubeSat mission to Mars

Mars Cube One or MarCO are two 6U CubeSats (MarCO A and B) that will be the first CubeSats to leave Earth's orbit when they are launched in May of this year.

They will go to Mars as part of NASA's InSight Mars landing mission and will act as telemetry relays for the lander.

Since the InSight vehicle is landing beyond line of sight from Earth, the CubeSats will establish a direct radio relay link to Earth.



Artist's impression of MarCO spacecraft relaying radio signals back to Earth as the InSight landing vehicle descends to Mars.

They are not crucial for the mission as the lander will retransmit its data directly to Earth when line of sight is established but they are intended to demonstrate that CubeSats can work beyond the constraints of Earth orbit and to act as relay stations for future missions. Presumably they could also be used for planetary imaging just as on Earth.

During the lander descent MarCO will receive data at 8kbps and relay it back to Earth at the same rate in the X-band (roughly 7 to 11GHz).

MarCO weighs around 14kg, can produce 35W from solar panels (at Earth-Sun distance but less at Mars) and has Vacco cold gas thrusters for manoeuvring and attitude control.

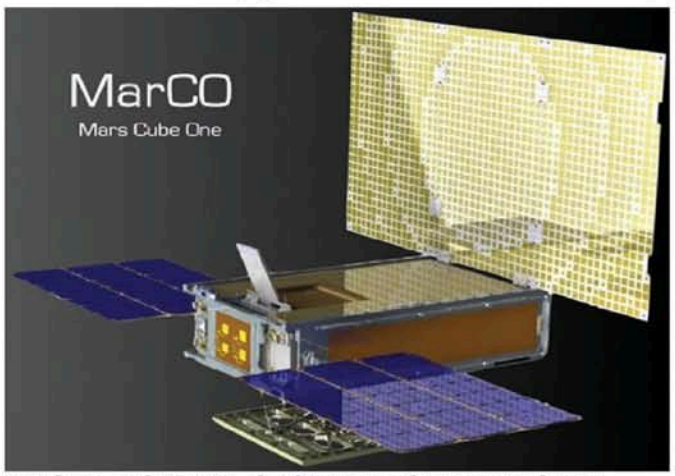
It uses standard 18650B batteries (as typically used in laptops, high performance torches and Tesla cars) configured as 3S4P. It will have a customised Iris V2 software-defined radio with a transmit power of 4W. Attitude determination and control will be reaction wheels, a gyro sun, sensors and a star tracker.

Video: *"MarCO: First Interplanetary CubeSat Mission"* https://youtu.be/dS_Q7BFGuu0

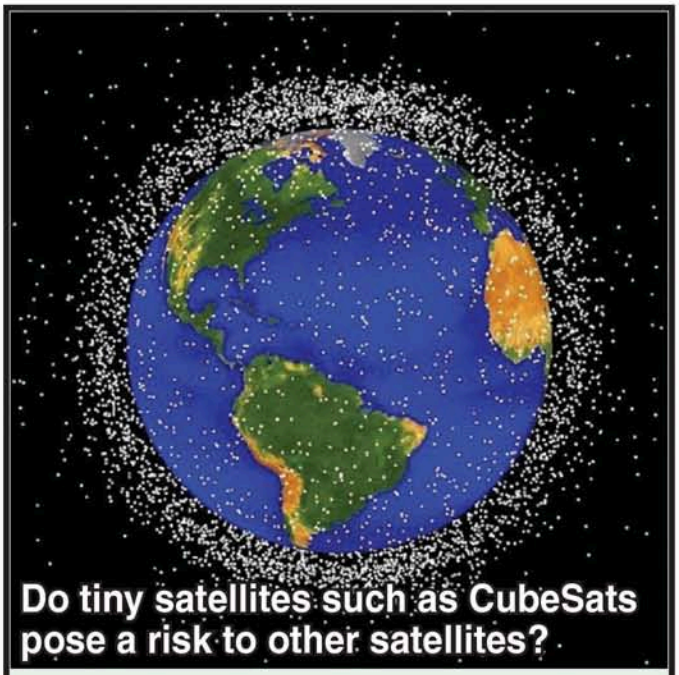
Where to next?

We have seen how small size satellites, especially those in the CubeSat form factor can provide daily imagery of the Earth, can go to the moon and even go to Mars. They are also within the capability of small, budget-constrained groups to design, build and have launched.

So where will they go next? SC



Rendering of MarCO, the first interplanetary CubeSat.



Do tiny satellites such as CubeSats pose a risk to other satellites?

In August 2016, the European Space Agency reported that a <5 mm fragment of space junk collided with its Sentinel 1A spacecraft – and tore a hole nearly half a metre wide in one of its solar panels. Unfortunately, that produced yet more space debris!

It's not the first collision in space. In our story on the Iridium Satellite Phone system (SILICON CHIP, November 2017) we told how in 2009 an errant "dead" Russian satellite (Kosmos 2251) collided with, and destroyed, the new Iridium-33 satellite.

A French satellite was hit and damaged by debris from a French rocket which exploded ten years earlier. And a Chinese test, which used a missile to destroy an old weather satellite, added more than 3000 pieces to the debris problem.

Even the Hubble telescope has had significant damage to one of its cameras, probably caused by a collision in space.

At last count, NASA estimated there were more than *150 million* fragments of space debris, ranging from a millimetre to many tens of metres in size. Half a million are larger than a marble – and at the speed they travel, they can do immense damage.

The problem is, basically, that when satellites are decomissioned, most are left in orbit – indeed, many are out of fuel so ground controllers can do nothing to move them out of the way.

Enter the CubeSats

The low-Earth orbit area used by the majority of CubeSats is getting increasingly cluttered, not just with junk but with the hundreds of CubeSats being deployed each year. Many of these will have a relatively short-term decaying orbit then will re-enter the Earth's atmosphere and burn up. Problem solved?

But many won't – and they will add to the growing concern for space scientists. In fact, both NASA and the ESA have departments specifically set up to track space junk. Even though current international guidelines recommend satellites be removed from orbit within 25 years, experts say that's simply not fast enough.

Where spacecraft are manned (eg, the ISS), NASA draws an imaginary box measuring 50km x 50km x 1.5km around the craft.

If their monitoring predicts that any debris or another spacecraft will pass within this box, plans are made to move the craft slightly, to "batten down the hatches" in the craft and/or to move the crew to the safety of the more secure transport spacecraft.

Can YOU master the THEREMIN?

If you play video games, you'd be aware that some can be played with hand gestures – you're not actually touching the game itself. Similarly, some phones and tablets can be controlled by gestures. But there's a musical instrument which also plays with hand movements – and it pre-dates games and phones by nearly a century. It's called the Theremin (pronounced ther-er-min) which produces some really eerie, almost spooky, sounds. And you can build one yourself. Whether you can master it . . . well, that's another story!

By JOHN CLARKE

The eerie sounds of this almost mystical instrument have featured in many recordings and movie sound tracks right up to the present – despite being invented by Léon Theremin in 1919!

SILICON CHIP has published six Theremin designs over the years but this is the first which uses transistors rather than ICs. Nor does it have any surface mount devices, so it is really easy to build and getting it to work is simply a matter of adjusting a couple of thumbwheel knobs.

While all our previous designs have been quite popular, some of our readers have hankered for a simple, discrete design and have asked us to revise the Theremin published in *Electronics Australia* in June 1969, in an article by some bloke called Leo Simpson.

Simple it was . . . but that design did not have a PCB and it required carpentry and other skills to put it together.

Accordingly, while we have changed the fifty-year-old circuit very little, we have brought the presentation up to date. As long as you can solder components to a PCB, you will find it easy to put it together.

The revised design uses slightly different transistors because some of those originally specified are now unavailable. In addition, you can run it from a 9VAC plugpack or even a 12V battery.

Unlike some commercial Theremins with a bewildering array of controls, there are just two on our Theremin, just like the original invention.

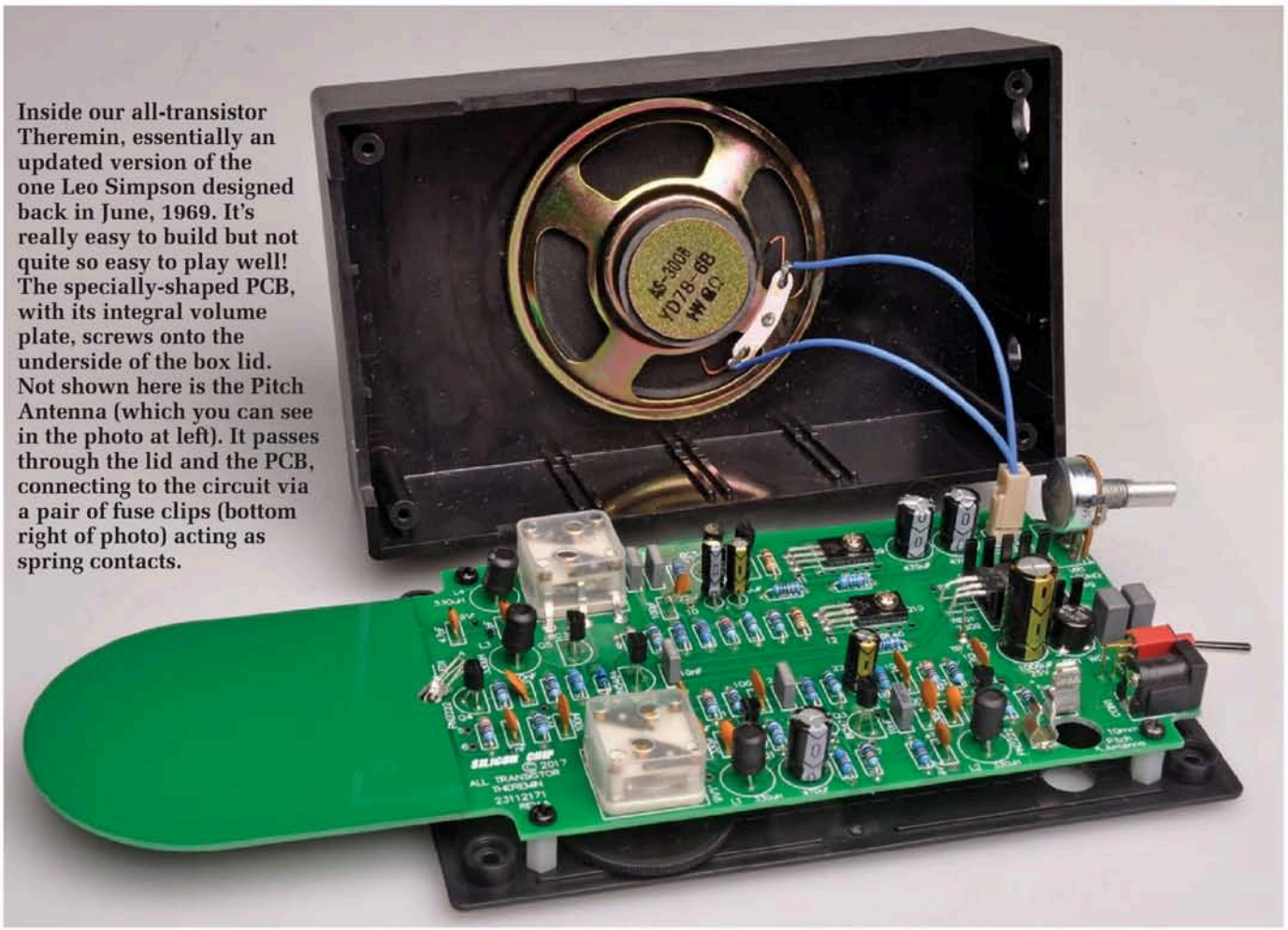
One is a vertical "antenna", which is the pitch control. You vary the pitch by moving one hand near the antenna.

The man himself, playing the instrument he invented in 1919. Theremin wowed audiences on three continents.

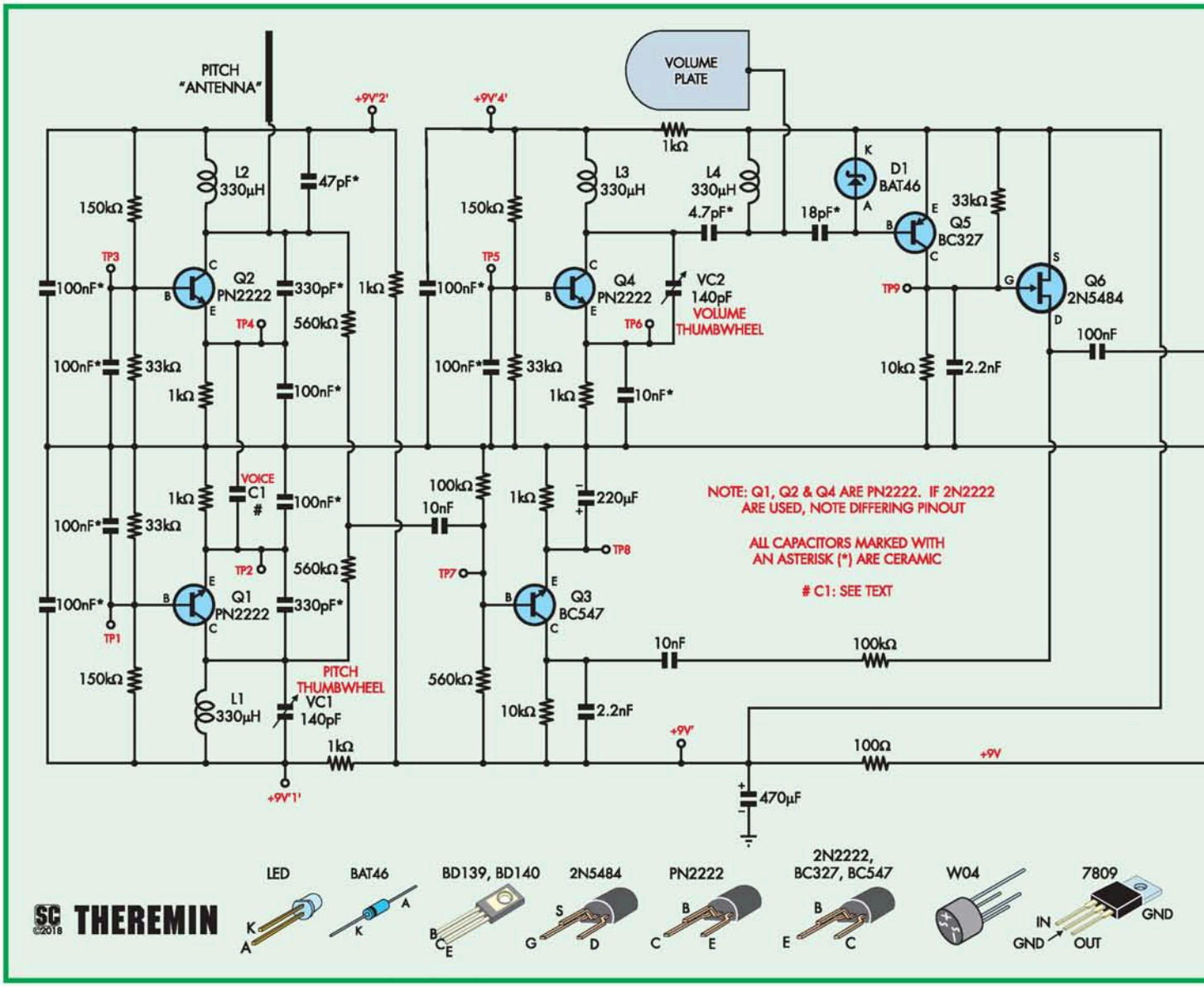
As well as merely changing the pitch, you can add vibrato effects by fluttering your hand or fingers near the antenna. Moving your hand from one position to another by a very small amount will produce a gliding tone or glissando effect; you cannot easily play discrete notes.

(Incidentally, we have retained the traditional name, "antenna", for the Theremin's pitch control, even though it doesn't really transmit or receive anything. In addition, it resembles a whip antenna on a portable radio).

The other control is a horizontal plate and it is used to



Inside our all-transistor Theremin, essentially an updated version of the one Leo Simpson designed back in June, 1969. It's really easy to build but not quite so easy to play well! The specially-shaped PCB, with its integral volume plate, screws onto the underside of the box lid. Not shown here is the Pitch Antenna (which you can see in the photo at left). It passes through the lid and the PCB, connecting to the circuit via a pair of fuse clips (bottom right of photo) acting as spring contacts.



vary the volume. As well, you can add tremolo effects (similar but not the same as vibrato) by fluttering your hand or fingers above the volume plate. All this waving and fluttering of your hands near the controls is merely using capacitance effects to vary the circuit performance but the fact that you don't actually touch anything makes the process seem all the more clever to an audience.

Playing a Theremin is not particularly easy but if you have a good musical "ear" and you can play a stringed instrument like a violin or cello, or perhaps a trombone, you will have a head start in making music.

Heterodyning

Basically, the audio tone or musical note is produced by heterodyning (or mixing) two radio frequency oscillators to produce an audible beat or difference frequency. Some readers may have heard a similar kind of whistle, produced when a shortwave radio receiver is tuned across the dial. By carefully manipulating the receiver dial, it is possible to produce a beat ranging from a high frequency whistle to a low frequency growl.

The two oscillators in a Theremin, used to produce the audible beat, must be set up so that they can operate very close together in frequency and without too obvious a tendency to lock at the same frequency. One oscillator must be designed so that its frequency will change readily when a hand is brought close to the pitch antenna. The other oscillator remains fixed in frequency.

With both oscillators on the same frequency, there is a zero beat and no audible note is heard from the loudspeaker. When a hand is brought near the antenna, the frequency of the variable oscillator changes and a beat note is produced.

Circuit details

The two oscillators controlling pitch utilise NPN PN2222 transistors (Q1 & Q2). These are connected in a Colpitts configuration with an operating frequency of around 470kHz.

By the way, a Colpitts oscillator is a type of LC oscillator which lends itself very nicely to this type of circuit. You can find a lot more information on line.

The pitch antenna is connected to the collector of Q2, so bringing a hand close to the antenna will alter its ca-

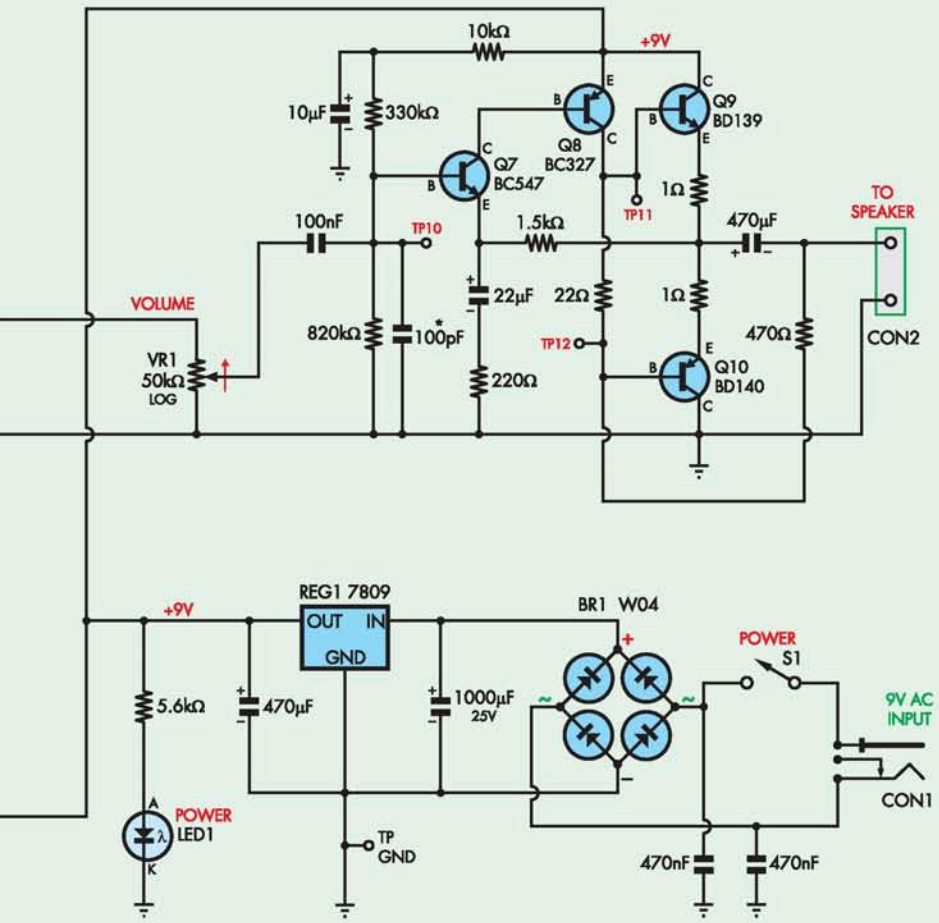


Fig.1: two radio frequency signals, generated by oscillators based on Q1 and Q2, are heterodyned (or mixed), to produce an audio frequency note which can be varied by the distance of the hand from the pitch antenna. A slighty different arrangement, but also based on hand/plate capacitance, varies the volume fed to a conventional audio amplifier and small loudspeaker.

pacitance and therefore will vary its frequency.

The other pitch oscillator involving Q1 is tuned with a 140pF adjustable trimmer capacitor VC1. This trimmer is a standard plastic dielectric tuning capacitor normally used in small AM radios but only one section is used.

A similar circuit arrangement is used for the volume control. Both trimmer capacitors are fitted with thumbwheels so that they can be easily adjusted.

The waveform from both oscillators is very clean and as a result, the basic beat note would normally be fairly pure. If the two oscillators were run from the same supply they would tend to lock to the same frequency when they came within a few hundred Hertz of each other. This would mean that the beat frequency would not range smoothly down to the low bass region. For this reason, the supply rail for each oscillator is decoupled via a 1kΩ resistor and 100nF ceramic capacitor.

As a result, the two oscillators will not lock until the beat frequency is just a few Hz; a very low growl. It is desirable that the oscillators do eventually lock though, otherwise it would be too difficult to adjust VC1's thumbwheel for a zero beat.

In the original Theremin circuit, the oscillator transistors were Philips BF115 RF devices but these are now obsolete. So we are using cheap PN2222 general purpose transistors which have a very respectable frequency gain (f_T) product of 250MHz so they have no trouble oscillating at 470kHz.

The output from each oscillator is fed via 560Ω resistors to a mixer stage consisting of a general purpose BC547 NPN transistor, Q3, connected in common-emitter configuration.

The mixer has four output frequencies: the two oscillator frequencies at around 470kHz, the sum of the two frequencies (around 940kHz) and the difference between the two frequencies, which is the audible output.

The BC547 does not have a lot of RF gain and the 2.2nF capacitor shunting the collector load resistor further attenuates the RF components, leaving the wanted audible output. The mixer stage is slightly over-driven to add harmonics, so that the sound will be subjectively more interesting.

A small change we made to the original circuit is to include the option of coupling between the pitch and reference oscillators using C1, which provides for "voicing".

When the pitch oscillator frequency differs from the reference oscillator so we get an output tone, the difference in frequency between the two oscillators tends to pull or distort the beat frequency wave shape so that it is not a sinewave.

Typically, for a Theremin we want a sound that resembles a cello at low frequencies, morphing to something more like a flute as the frequency rises.

Adding capacitor C1 allows you to experiment to obtain a different sound – try values from about 220pF to 470pF.

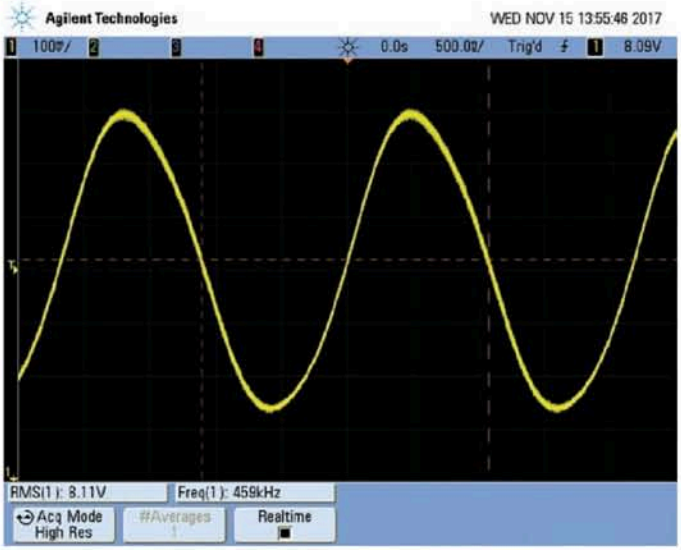
Voltage controlled attenuator

The output from the collector of Q3 is fed to a voltage divider consisting of a 100kΩ resistor and the drain-source resistance of N-channel JFET, Q6.

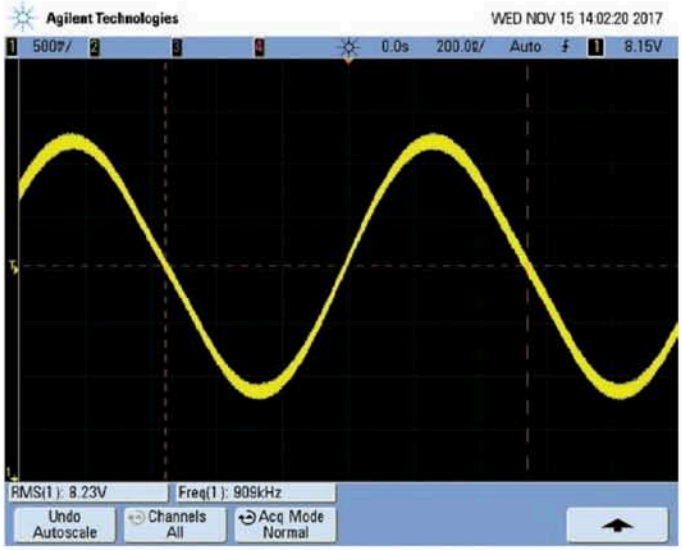
The resistance of Q6 is dependent on the gate source bias which is provided by the volume control circuitry, involving an oscillator using Q4, the capacitance plate and DC amplifier, Q5.

Q4 is another PN2222 NPN transistor and the volume oscillator is also a Colpitts type, running at around 900kHz. The volume oscillator also has its supply decoupled via a 1kΩ resistor and 100nF capacitor.

The output of the volume oscillator is fed, via a 4.7pF ceramic capacitor, to a parallel tuned circuit consisting of a 330µH RF choke and the capacitance of the volume plate. A portion of the signal across the tuned circuit is coupled to schottky diode D1, via



Scope 1: this signal is the output of the "pitch" reference oscillator (based on Q1) which is adjusted in frequency by the pitch thumbwheel capacitor, VC1. Note that the output is quite clean.



Scope 2: similarly, the output of the "volume" oscillator based on Q4. This is adjusted by VC2. Both these measurements are difficult to make because of loading by the scope probe.

an 18pF capacitor.

The resulting DC voltage is amplified by PNP transistor Q5 and applied to the gate of the FET after filtering with a 2.2nF capacitor. The level of the audio tone being reproduced should decrease when a hand is brought near the volume plate.

Initially, the volume oscillator is adjusted, by means of 140pF rotary trimmer capacitor VC2, to give a minimum loudness of the audio tone when the hand is near the volume plate. This involves tuning the oscillator so that its frequency coincides with the resonant frequency of the tuned circuit.

As a result, the voltage derived from the diode will be at a maximum so that Q5 is forward biased and consequently, turned on. The gate of the FET is taken toward the positive supply rail and its drain to source resistance is held to a low value. This shunts a large portion of the beat note signal to the positive supply.

When you move your hand away from the volume plate, the capacitance in the tuned circuit changes the resonant frequency so that the DC derived from the diode decreases. This progressively carries Q5 toward cut-off so that the drain-source resistance of the FET increases. Thus more of the audio tone signal is fed to the following amplifier. At this point, a particular characteristic of the FET becomes apparent. For small voltages of either polarity (or AC) applied between the drain and source, the FET behaves as a resistor which can be varied in linear fashion by a voltage applied between source and gate.

With the gate voltage varying between zero to about 4V below the source, the relationship between gate to source voltage and drain to source resistance may be relatively linear but this is no longer true as the gate to source voltage approaches the pinch-off voltage of the FET.

In this region, the relationship becomes very non-linear, with a small increase in gate to source voltage resulting in very large change of drain to source resistance and so the FET is turned off over a small voltage range.

It means that, in a certain region near the volume plate, a small hand movement will result in a large change in loudness so that it tends to act almost as a switch. To reduce this effect, a 33kΩ resistor is connected between collector and emitter of Q5. When the transistor is turned off, the 33kΩ and the 10kΩ collector load resistor form a voltage divider which limits the FET gate to source voltage to about minus six volts. This has the effect of making the volume control action more progressive but it does reduce the available range of the control.

Note that it is not possible for the volume control circuitry to give zero sound output, since the minimum resistance of the FET is typically 100Ω and it cannot shunt all the signal to the positive supply.

To sum up, the pitch of the Ther-

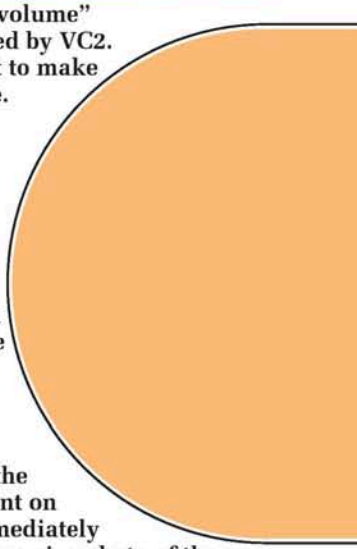
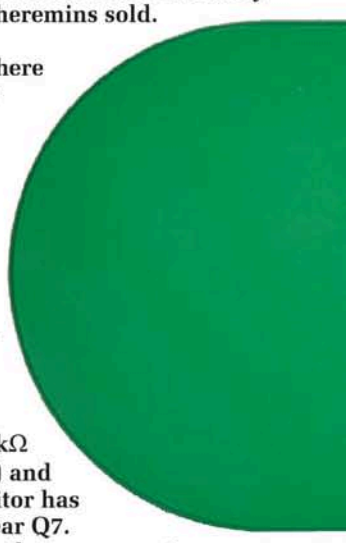


Fig.2: PCB component overlay for the Theremin showing were everything goes. All components, with the exception of the speaker, mount on this PCB. Immediately below is a same-size photo of the PCB, this time installed on the lid of the UB1 Jiffy box we used. If you were really keen, you could make a timber case, just like Theremin's original and, indeed, most of the early commercial Theremins sold.



Incidentally, there are two minor differences between the photo of the prototype at right (PCB Rev "A") and the final PCB/component overlay above (Rev "B"). The value of VR1 has been changed to 50kΩ (it was 100kΩ) and a 2.2nF capacitor has been added near Q7. Always follow the component overlay when assembling.

emin is controlled by beating two RF oscillators running at about 470kHz together, one of which is sensitive to hand capacitance. The resulting beat note can be varied over the whole of the audible range.

The loudness of the beat note is controlled by a third oscillator running at about 900kHz and feeding a tuned circuit which has its resonant frequency shifted by hand capacitance.

A DC voltage, derived from the tuned circuit, is used to vary the drain to source resistance of a FET, which is part of a voltage divider to which the beat note signal is applied.

Having grasped this, the rest of the Theremin is easy to understand. The signal from the FET attenuator is fed to a 50kΩ potentiometer and then to an audio amplifier and loudspeaker.

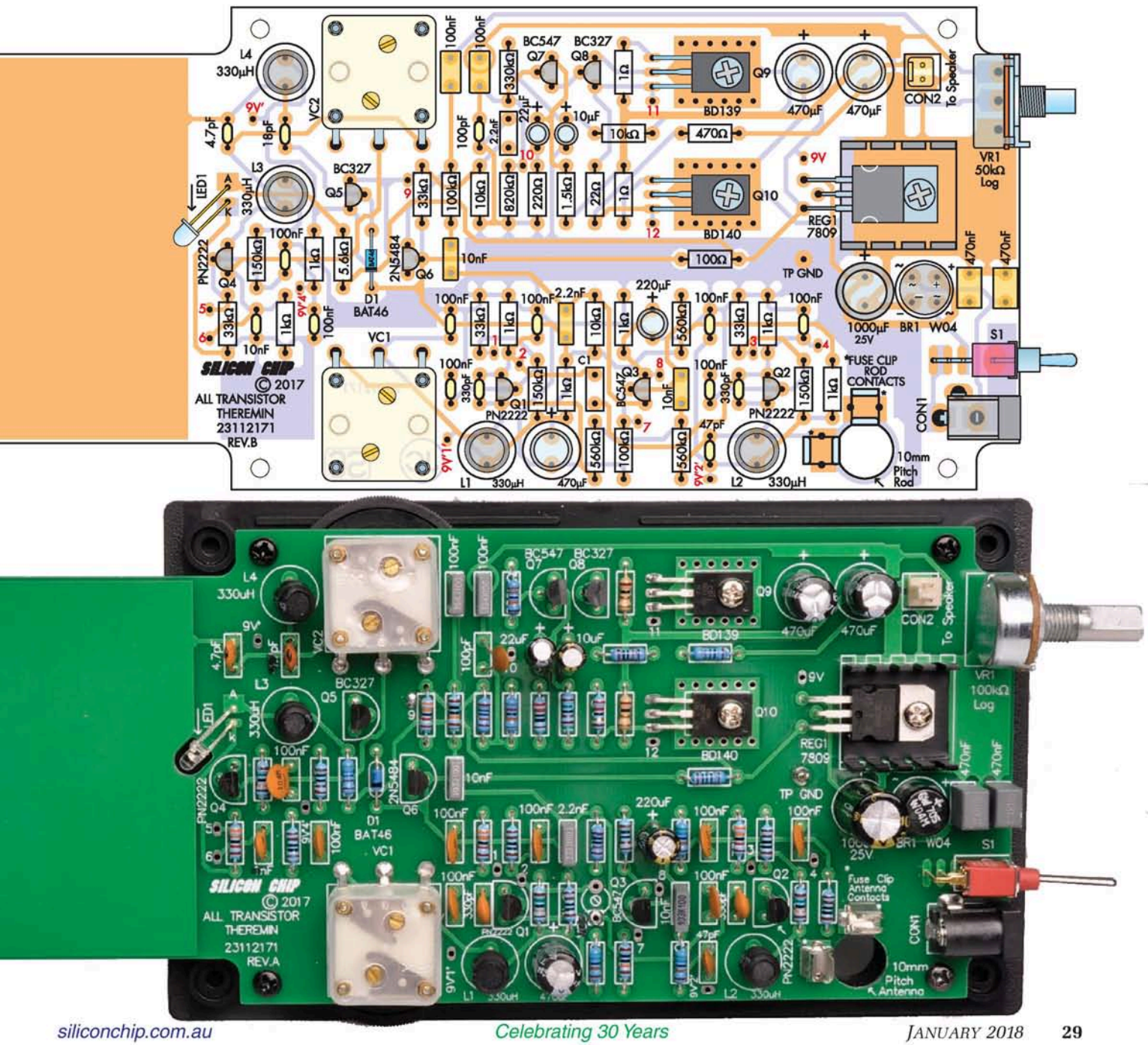
The 4-transistor amplifier is a conventional direct-coupled design with the two output transistors connected in the complementary symmetry mode but operating in pure class-B mode, ie, there is no quiescent current to reduce crossover distortion.

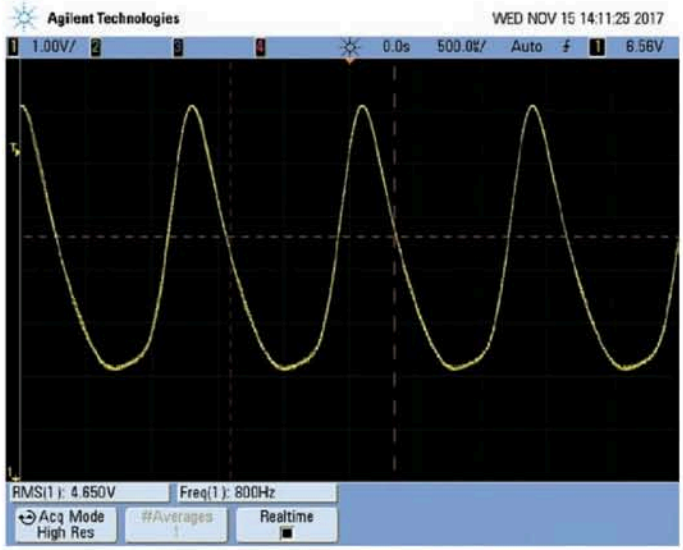
We are not concerned with crossover distortion in this design, partly since providing a quiescent current would increase overall current drain which is not desirable if operating the Theremin from a battery.

As it turns out, as you can see from the Scope 4 waveform, crossover distortion is not noticeable in the output.

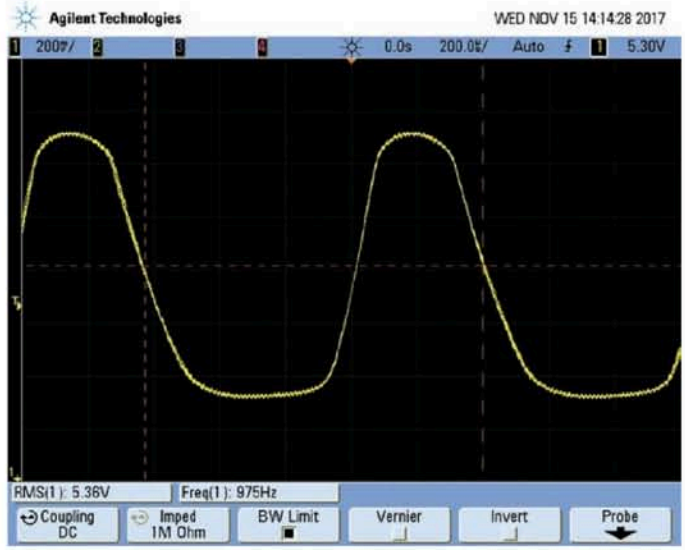
The total current drain is mostly due to the collector current of Q8, the class-A voltage gain stage of the amplifier. Maximum power output is about 400mW into an 8-ohm speaker.

One interesting point to note about the amplifier is that we are using a standard arrangement whereby the loading on the collector of Q8 is reduced by "boot-strapping" from the output. Instead of connecting the 470Ω collector load for Q8 to the 0V rail, we have connected to the speaker active terminal, ie, at the negative electrode





Scope 3: this scope grab shows the signal at the output of the mixer, Q3, measured at its collector. Its amplitude is varied by JFET Q6 before being fed to the volume control, VR1, and the audio amplifier.



Scope 4: the output from the audio amplifier, across the loudspeaker. Note that there is no visible crossover distortion despite the fact that there is no quiescent current in the output transistors: this is operating in pure class B.

of the 470µF output coupling capacitor.

By dint of the emitter-follower action of output transistors Q9 & Q10, the AC load impedance "seen" by the collector of Q8 is a great deal higher than 470Ω.

In effect, because of the emitter-follower action, the AC voltage (ie, the audio signal voltage) is virtually the same at either end of the 470Ω resistor and therefore the AC current is greatly reduced.

Note that the small DC load current of Q8 flows through the voice coil of the loudspeaker to the 0V rail.

This improves the gain, linearity and output voltage swing of Q8. The only potential drawback of this circuit is that if the loudspeaker is disconnected, Q8 has no current path and therefore the amplifier latches up, drawing negligible current.

Power supply

Power for the circuit comes from a 9VAC plugpack. A 12V battery can also be used but may not give the performance of an AC supply. Note that a switchmode 12V DC supply is not suitable for this project due to the large amounts of harmonics and noise they normally emit – it's a fair bet that would either interfere with the oscillators, get into the audio amplifier . . . or both.

Switch S1 applies power to the circuit. The 470nF capacitors on each side of the input supply ground the AC connections and swamp any capacitance effects of the plugpack to ground. This ensures there are no spurious sounds from the Theremin due to the plugpack. As a side benefit, the 470nF power supply capacitors provide a virtual earth effect so that the hand capacitance is more effective for the pitch and volume controls.

The 9VAC is rectified by bridge rectifier BR1 and then filtered with a 1000µF capacitor to provide a relatively smooth ~12VDC supply for REG1, a 9V regulator that delivers a stable 9V DC to the circuit. A 470µF capacitor close to the regulator output ensures stability of the regulator and can provide any short term peak current for the amplifier. LED1 shows that the power is on.

By the way, we should also note that running the Theremin from battery power will have a drawback, since the virtual earth effect provided by those two 470nF capacitors. Therefore, the effects of hand capacitance may be reduced to some extent.

Construction

All of the circuit components are accommodated on a relatively compact PCB which also provides the volume control plate – making it easy to build. The pitch antenna is a 400mm length of 10mm aluminium tube, inserted into a hole in the front panel and PCB and making contact with the circuitry via two springy contacts, which are actually the contacts from a standard 3AG PCB fuseholder.

The two tuning capacitors are mounted directly on the PCB and their thumbwheels protrude slightly from each side of the box, in our case a standard plastic UB1 Jiffy box.

Begin construction by installing the resistors. You can check the colour code for each resistor value by referring to the table of resistor values later in this article.

However, whether or not you are familiar with the resistor colour code, we strongly suggest that you check each resistor value with a digital multimeter before it is inserted and soldered into place (some colour bands are notoriously similar to others).

Resistors are not polarised and can be inserted either way into the board. But it is good practice to install them so that their colour codes all align in the same direction (eg, tolerance band at the bottom or on the right). This makes it so much easier to check their values later on.

The four 330µH inductors can be placed now.

Next, install the capacitors. There are three types used in this circuit. One type is MKT polyester, recognised by their small "block" shape. The second type is disc-shaped ceramics.

Neither polyester nor ceramic capacitors are polarised – they can be inserted either way around. They are usually marked with a code (shown in the small capacitor code table) to indicate their capacitance.

The third type of capacitors are the electrolytics. These are (usually) cylindrical in shape and with rare exception (and none in this circuit) are polarised – they must be inserted the right way around, as shown on the PCB overlay. They have a polarity marking of "–" symbols along one side which indicates the negative lead.

Next to go in are the semiconductors, all of which are polarised. Install diode D1 and the bridge rectifier, BR1, followed by the transistors.

Make sure you put the correct transistor in each position – some look identical.

Note that the PCB is designed for the PN2222A transistors for Q1, Q2 and Q4. If using 2N2222A transistors, they will require insertion at 180° to that shown on the PCB overlay, with the base lead bent back to fit the PCB hole position.

Transistors Q9 and Q10 are mounted horizontally with the metal face toward the PCB. Their leads are bent down 90° to insert into the PCB holes.

As well as soldering, these transistors are attached to the PCB with M3 x 10mm screws and nuts with the screw placed from the solder side of the PCB and the nut on the transistor. Attach the screw and nut before soldering to ensure they fit in the right position.

REG1 is mounted horizontally, similarly to Q9 and Q10 but is mounted on a small heatsink that is sandwiched between it and the PCB. Bend the leads down 90° before inserting into the PCB, secure the tab to the heatsink and PCB using an M3 x 10mm screw and nut and then solder the leads in place.

CON1 and S1 can be installed now. Make sure these two parts are mounted hard up against the PCB before soldering.

The two fuse clips which make contact with the pitch antenna can then be soldered in. The clips may require opening out a little to ensure a good contact with the 10mm aluminium tube antenna.

CON2 is for making connection to the loudspeaker. Install the 2-pin header on the PCB. The 2-pin socket is wired to ~100mm lengths of hookup wire by crimping the wire ends to the crimp connectors first (you can solder these too for a secure joint) and then inserting into the socket shell. The other ends of the wire are soldered to the loudspeaker terminals.

LED1 mounts horizontally inside the cutout in the PCB, with the leads bent to insert into its holes in the PCB. Make sure the polarity is correct – the longer lead is its anode.

The two plastic dielectric tuning capacitors (VC1 and VC2) are secured to the PCB by two short M3 screws (they should be supplied with the capacitors). Their three tag leads need to be bent at right angles to insert into the holes on the PCB. They are then soldered in place.

Cut the potentiometer shaft to 12mm in length from its end to where the threaded boss starts. Snap off the location spigot and install onto the PCB.

Testing

Check your construction carefully to make sure there are no mistakes – especially the orientation of all polarised components (electrolytic capacitors, diode, transistors and regulator) and the right components are in the right places.

If you are satisfied that all is correct, plug in your 9VAC plugpack (or 12V DC battery – positive to centre pin) and switch on. LED1 should light up. We have included quite a few test points on the PCB. These are labelled from one

Parts List – Theremin

1 PCB coded 23112171, 226 x 85mm (includes integral volume plate)
1 UB1 Jiffy box 158 x 95 x 53mm
1 9VAC 350mA plugpack
1 ~400mm length of 10mm diameter aluminium tube (for pitch antenna)
2 Mini tuning gang capacitors (includes thumbwheel and mounting screws) (VC1,VC2) [Jaycar RV-5728]
4 330µH chokes (L1-L4) [Jaycar LF-1106 Altronics L 7040]
1 3" loudspeaker (4Ω or 8Ω)
1 knob to suit pot
1 PCB mount SPDT toggle switch (S1) [Altronics S 1421]
1 PCB mount DC socket (2.1 or 2.5mm) (CON1)
1 mini heatsink 19 x 19 x 9.5mm
2 M205 fuse clips
4 M3 tapped x 9mm standoffs
11 M3 x 10mm screws (4 are optional. See text)
3 M3 nuts
1 2-way pin header socket
1 2-way pin header plug (CON2)
4 stick-on rubber feet (the taller the better!)
1 PC stake for TP GND
1 15mm length of 10mm diameter heatshrink tubing

Semiconductors

3 PN2222 NPN transistors (Q1,Q2,Q4) [or 2N2222A (see text) Jaycar ZT-2298; Altronics Z 1166]
2 BC547 NPN transistors (Q3,Q7)
2 BC327 PNP transistors (Q5,Q8)
1 2N5484 JFET (Q6)
1 BD139 NPN transistor (Q9)
1 BD140 PNP transistor (Q10)
1 BAT46 schottky diode (D1)
1 7809 9V regulator (REG1)
1 W04 1A bridge rectifier (BR1)
1 3mm high intensity blue LED (LED1)

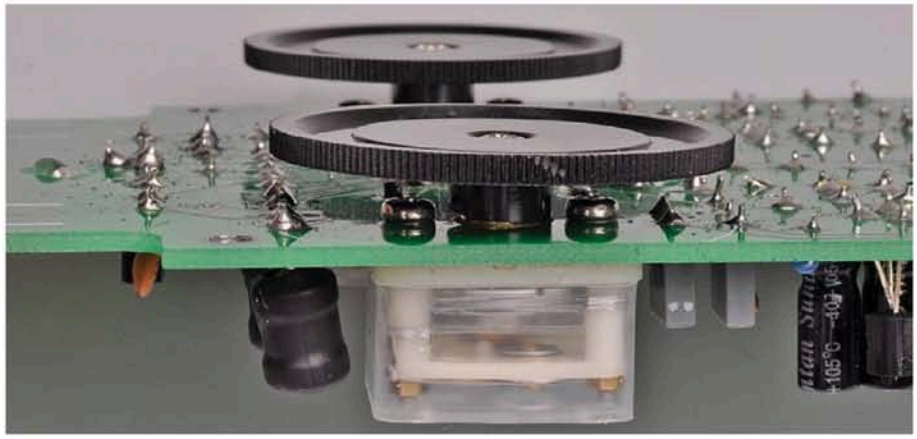
Capacitors

1 1000µF 25V PC electrolytic
3 470µF 16V PC electrolytic
1 220µF 16V PC electrolytic
1 22µF 16V PC electrolytic
1 10µF PC electrolytic
2 470nF MKT polyester
2 100nF MKT polyester
2 10nF MKT polyester
2 2.2nF MKT polyester
8 100nF ceramic
1 10nF NP0 (COG) ceramic
2 330pF NP0 (COG) ceramic
1 100pF ceramic
1 47pF NP0 (COG) ceramic
1 18pF NP0 (COG) ceramic
1 4.7pF NP0 (COG) ceramic

Resistors (0.25W, 1%)

1 820kΩ	3 560kΩ	1 330kΩ	3 150kΩ	2 100kΩ
4 33kΩ	3 10kΩ	1 5.6kΩ	1 1.5kΩ	7 1kΩ
1 470Ω	1 220Ω	1 100Ω	1 22Ω	2 1Ω 5%

1 50kΩ 16mm log pot (VR1)



This close-up of the PCB shows how the two variable capacitors (actually mini AM radio tuning gangs) are fastened in place. If you find the knob catches or binds on the board or case, you may need to adjust the position or deepen the slot.

through to twelve, with additional test points labelled TP GND, 9V, 9V', 9V1', 9V'2 and 9V'4.

Connect the negative lead of your multimeter to TP GND. TP 9V should measure close to 9V (but can range from 8.85 to 9.15V). Test point 9V' should be around 8.6V and test points 9V'1', 9V'2' and 9V'4' should be around 8V to 8.6V.

Test points 1, 3 & 5, should be about 1.0V, although TP5 might be a little lower at around 0.8V instead. TP2, 4 & 6 should be at 0.4V, with TP6 possibly as low as 0.22V. TP7 should be around 1.1V and TP8, 0.6V. Test point 9 will depend on the setting of VC2, but should be in the range of 2V to 8.6V and adjustable with VC2.

Test point TP10 should be 6.2V. Connect the loudspeaker for the next readings. You should measure 5.5V at TP11 while TP12 should be around 5.3V.

If all the voltages measure correctly, remove power ready for installation in its box.

Housing

We housed our Theremin in a UB1 Jiffy box (as we believe most constructors will do) but for authenticity, you might like to make your own timber box just like Léon Theremin's original design (and most early models). That's up to you.

The PCB is mounted upside-down on the lid of the box (so that the component side is facing downward). If you make a timber box, it should have the same or similar arrangement. Four 3mm holes in the lid hold the PCB in place.

Three slots need to be cut in the top edge of the box itself. One is to allow the volume plate (part of the PCB) to emerge from the left side, while two others allow the dials attached to VC1 and VC2 to emerge from the front and back.

Other holes required are in the right end (7mm for the volume control pot, 10mm for the power socket; 5mm for the power switch) along with one 10mm hole in the box lid for the Pitch Antenna to pass through (plus the four already mentioned for holding the PCB in place). The base of the box will also need a series of holes to let the sound out for the loudspeaker.

We have provided diagrams for all of these holes. You can either measure and mark the hole positions or photocopy the diagrams and use them as templates (or download the diagrams from siliconchip.com.au, print those out and use them as templates).

Attach the two thumbwheels to VC1 and VC2 with the supplied M3 screws. Make sure that the thumbwheels do not bind against the PCB when they are rotated.

If they do, you may need to file a little off the thumbwheel bush to provide extra clearance above the PCB.

Glue the loudspeaker to the base of the box using contact adhesive, silicone sealant or similar. Rubber feet are attached to the underside of the box to raise it for sound to escape.

Installation in the box

While the PCB can be secured to the box by means of the potentiometer nut, we elected to also secure the PCB to the lid of the box using four 10mm M3 tapped spacers, each with a 5mm M3 screw top and bottom. (Alternatively, you could use 10mm untapped spacers with a 20mm M3 screw and nut, right through from the front panel).

This approach does make the installation of the PCB in the box slightly more difficult but it can be done – as our photos prove!

Resistor Colour Codes

	Qty	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	820kΩ	grey red yellow brown	grey red black orange brown
❑	3	560kΩ	green blue yellow brown	green blue black orange brown
❑	1	330kΩ	orange orange yellow brown	orange orange black orange brown
❑	3	150kΩ	brown green yellow brown	brown green black orange brown
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	4	33kΩ	orange orange orange brown	orange orange black red brown
❑	3	10kΩ	brown black orange brown	brown black black red brown
❑	1	5.6kΩ	green blue red brown	green blue black brown brown
❑	1	1.5kΩ	brown green red brown	brown green black brown brown
❑	7	1kΩ	brown black red brown	brown black black brown brown
❑	1	470Ω	yellow purple brown brown	yellow purple black black brown
❑	1	220Ω	red red brown brown	red red black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	22Ω	red red black brown	red red black gold brown
❑	2	1Ω#	brown black gold gold	(#: 5%) n/a

Small Capacitor Codes

	Qty	Value/Type	EIA	IEC
❑	2	470nF MKT	474	470n
❑	2	100nF MKT	104	100n
❑	2	10nF MKT	103	10n
❑	2	2.2nF MKT	222	2n2
❑	8	100nF ceramic	104	100n
❑	1	10nF ceramic	103	10n
❑	2	330pF ceramic	331	330p
❑	1	100pF ceramic	101	100p
❑	1	47pF ceramic	47	47p
❑	1	18pF ceramic	18	18p
❑	1	4.7pF ceramic	4.7	4p7

Learning more about the Theremin (and even learning how to play it!)

The internet has thousands of examples of Theremin exponents. (just Google "Theremin"). Many of them are brilliant musicians and they really know how make this instrument literally "sing".

One of the best is actually Léon Theremin's grand-niece – Lydia Kavina's demonstration at www.bbc.com/news/magazine-17340257 is only a couple of minutes long but is well worth watching. On the same page is an interesting article by Martin Vennard, of the BBC World Service, about Léon Theremin and the instrument he invented.

Lydia Kavina demonstrates the instrument her great-uncle invented.

Kavina's Theremin rendition of Debussy's Clair de Lune is simply enchanting. Search online for her other music.

Another masterful example of Theremin playing is in the nearly 17-minute long video at https://youtu.be/MJACNHHuGp0, where Carolina Eyck, a German composer and Theremin player (reputed to be one of the world's best) not only demonstrates her prowess on the instrument but as she does, she explains in some detail just how she plays it.

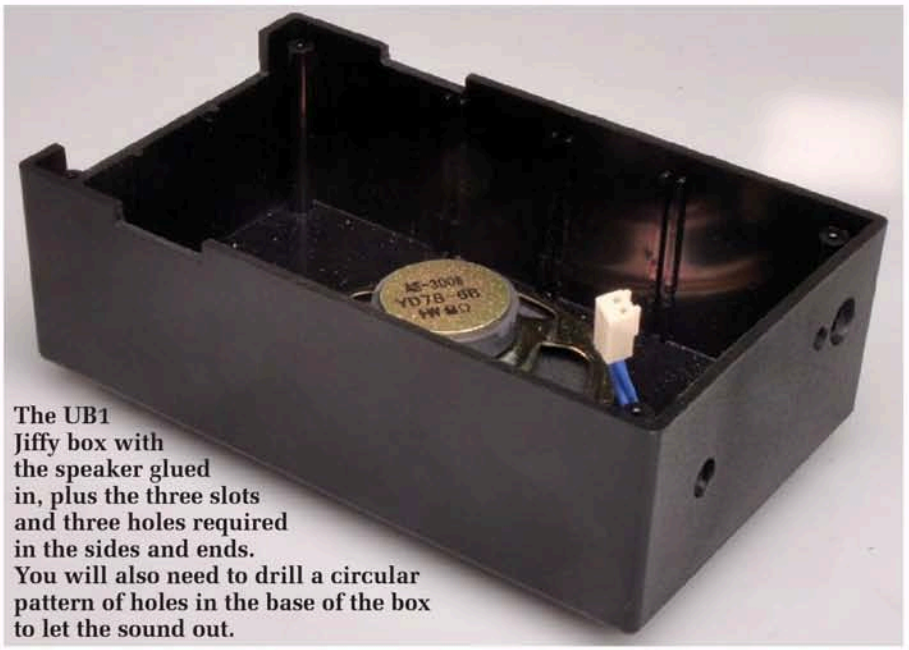
Admittedly, the Theremin she plays is considerably more complex (and expensive!) than our simple model and offers a range of user controls which would scare off all but the most expert of players. But this video will help you gain a real understanding of the intricacies of the Theremin – especially if you want to get more from it than just the usual howls and squeals of a novice player!

Carolina Eyck explains what the Theremin can do!

Slide the box lid/PCB assembly into the box with the switch lever and potentiometer shaft emerging through the holes in the right end. Then secure the potentiometer with its nut.

Install the antenna before making adjustments. The antenna is inserted 24mm into the top lid. We placed a 10mm diameter length of heatshrink tubing at the lower end of the Aluminium tube to mark when to stop any further insertion of the tube into the box.

Ensure that the two thumbwheel knobs for VC1 and VC2 can move freely within the box when the lid is in place. If they bind, you may need to deepen the slots they sit in. If all is OK, secure the lid to the box with its screws.



The UB1 Jiffy box with the speaker glued in, plus the three slots and three holes required in the sides and ends. You will also need to drill a circular pattern of holes in the base of the box to let the sound out.

Adjusting for pitch and volume

Set VR1 at mid position, plug your power supply in and turn it on. Adjust the volume thumbwheel and pitch thumbwheel till a sound can be heard, then set the volume thumbwheel so that sound can be heard even when the hand is near the plate. Adjust the pitch thumbwheel with left hand index finger and hand over the volume plate. That is so the hand is kept away from the pitch antenna.

Adjust the pitch thumbwheel trimmer for a zero beat with your hand away from the pitch antenna. Frequency should rise as your hand is brought near to the antenna. With your hand close to the volume plate, adjust the volume control trimmer for a minimum loudness.

Note that it is not possible for the volume trimmer to completely turn off the sound, for the reason already explained. These adjustments will have to be repeated each time the unit is set up in a different position.

You will find the Theremin is capable of an endless variety of sounds.

This photo shows the PCB mounted on the box lid, ready for installation. The PCB "hangs" from the box lid with the components underneath. The pitch antenna goes through the lid, through a matching hole in the PCB and is held in place with the spring fuse clips you can see near the power switch (left end).

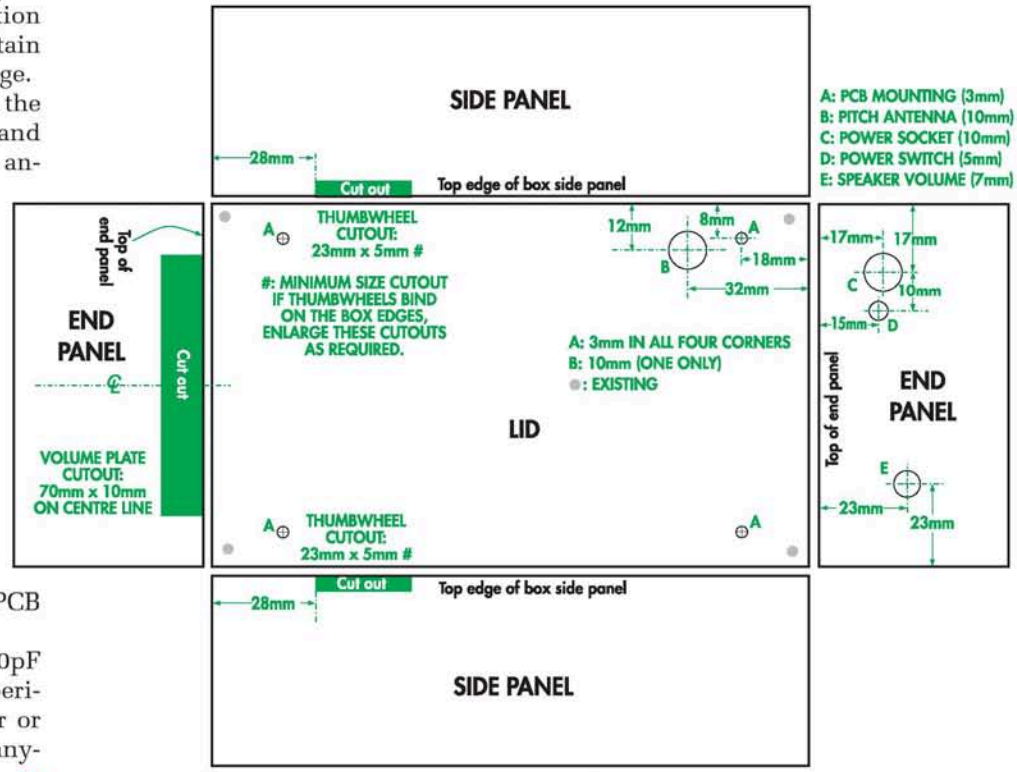
Low grunts and growls can be produced by a quick, sweeping motion of the hands. Similarly, one can obtain wails and squeaks in the high range.

To produce a vibrato effect, hold the volume hand in a fixed position and flutter the pitch hand near to the antenna at the desired rate.

Finer changes can be made by moving the fingers while the hand remains still. Similarly, to create a tremolo effect, hold the pitch hand in a fixed position and flutter the volume hand. (You will see the two ladies playing the Theremin in our examples [see panel] make extensive use of their fingers).

As we mentioned earlier, if you are interested in altering the voicing, you can add in capacitance between the emitters of Q1 and Q2, shown on both the circuit and PCB overlay as C1.

Somewhere around 220pF to 470pF is a good starting point when experimenting but you could go higher or lower than this without risking anything. SC



(Above): this drilling/cutting diagram for the UB1 Jiffy Box is reproduced half size so you will need to enlarge it 200% if using as a template.

The front panel we glued to the box lid for a really professional finish. This can also be downloaded from siliconchip.com.au if you want to print it on heavier or glossy stock.

PCBCART

Exceptional, Cost-effective Full Turnkey PCB Service from China's most experienced provider

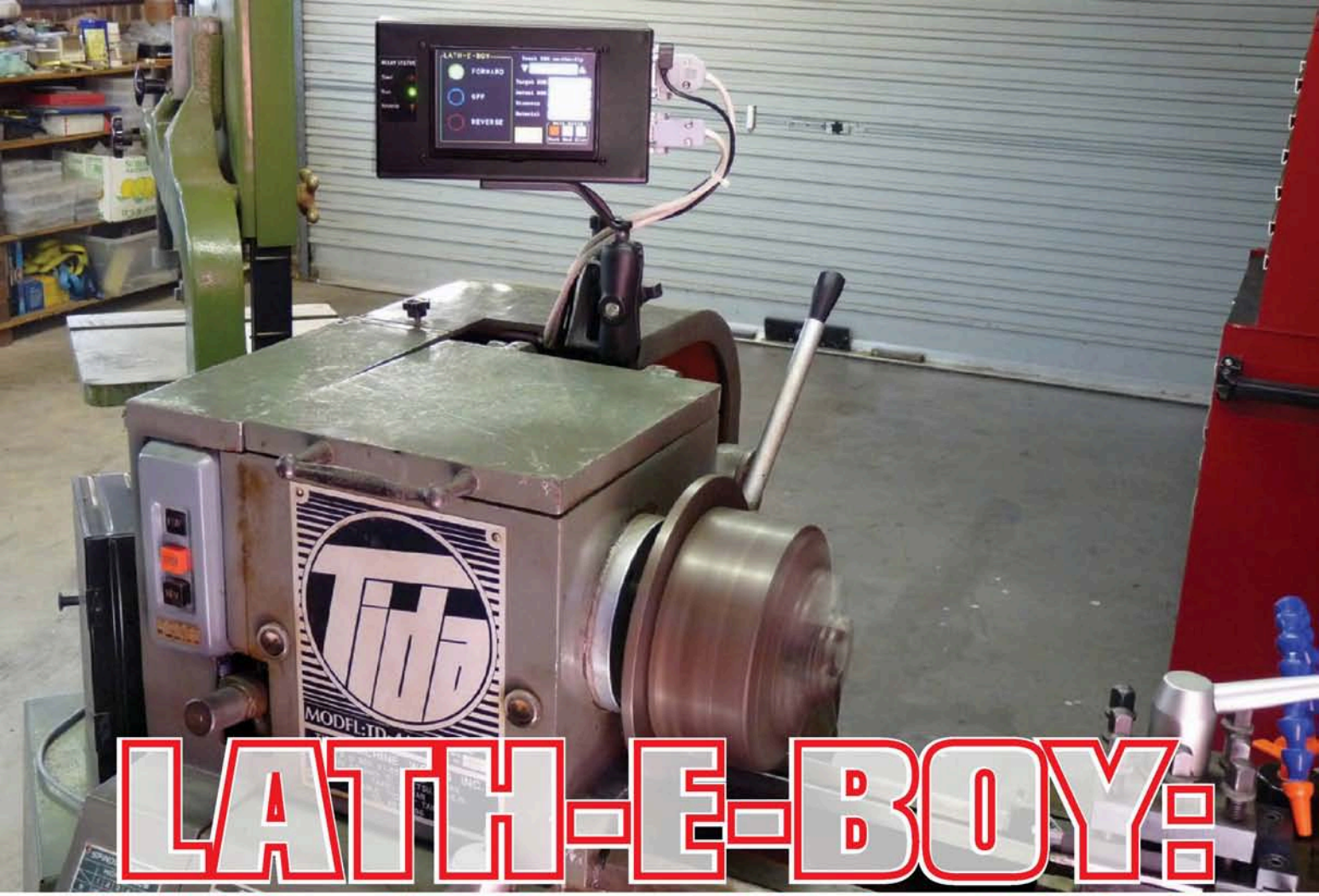
With 10+ years' experience serving tens of thousands of international clients, our expanded custom PCB manufacturing, assembly and parts sourcing capabilities allow us to fulfill almost all kinds of PCB needs at reasonable price.

We insist each electronic project (including those still at prototyping stage) deserves superior quality PCB services, that's why we follow the strictest quality standards during production. Got a project ready to bring into reality? We're happy to discuss.

ISO 9001 · Pb LEAD FREE · UL

WWW.PCBCART.COM

sales@pcbcart.com



LATH-E-BOY:

An Intelligent Touchscreen Lathe Speed Controller

This design combines two very popular projects, the Induction Motor Speed Controller and Micromite Plus Explore 100 with 5-inch Touchscreen, then adds some other circuitry, to provide an easy way to control a lathe. It automatically adjusts its speed to suit the material which is being turned and provides a constant display of the lathe's status and allows its speed and direction to be selected.

Most lathes, apart from small wood-turning lathes, are powered by an induction motor. The problem with using an induction motor is that up till now, the usual ways to control lathe chuck speeds involved belts and stepped pulleys or a gear box.

While they are still useful, it is now possible to control chuck speed and direction using our 1.5kW Induction Motor Speed Controller (IMSC), which was originally published in the April and May 2012 issues of SILICON CHIP (see siliconchip.com.au/Series/25).

But as well as providing those functions, why not provide extra features such as a speed read-out, touch-screen control interface and so on?

That's all doable by building an Explore 100 with the 5-inch touchscreen and then programming it to control the IMSC.

As you can see from the screen grabs in this article, the Lathe Controller interface is quite simple to use and saves you quite a bit of time and effort since all you need to do is specify the material type and diameter and it will automatically select a suitable motor RPM. You can then adjust this further if necessary.

And having selected the material type and/or spindle speed, you can then control the motor direction and fine-tune the speed, while monitoring the actual RPM.

This article gives all the details on how to add the extra circuitry required to the IMSC and Explore 100 and hook

Design by Peter Bennett Words by Nicholas Vinen

them up together, and to the lathe, to achieve this level of control.

Circuit description

The circuit for this project is shown in Fig.1, overleaf. It is broken up into several blocks, to reflect the physical layout of the system.

The large block at centre right represents the Micromite Plus Explore 100 unit, with LCD touchscreen. This is housed in a large Jiffy box, along with a few passive components, an optocoupler and four transistors.

These components interface the Explore 100 to the rest of the circuitry required to control the induction motor.

Those connections are made via two Cat5 cables which are plugged into 8-pin RJ-45 sockets CON2 and CON3 (note that CON3 only uses six of the eight available wires). Pins 1 & 2, 3 & 4, 5 & 6 and 7 & 8 are connected to the twisted pairs within the cable (but note that not all Cat5/6 cables are wired like this).

The connections made over Cat5 use current loops and, in the case of the motor speed control signal, 4kHz pulse-width modulation (PWM). It has been designed this way to allow for relatively long cable runs (of up to 50m). In most cases though, those cables will be a few metres at most.

With CON2, all eight connections between the two main modules (the IMSC Interface and the Explore 100) are optoisolated so that ground loops are not an issue, despite the possibility of a large distance between the units. This also prevents ground shifts due to the long wiring from affecting the accuracy of the control signals.

CON3 connects the Explore 100 control box to the relay box, which is wired between the outputs of the Induction Motor Speed Controller (shown at left) and the induction motor itself (at bottom right). The relay box switches the two windings of the motor to control start-up and direction of rotation.

The three high-current mains relays are driven by NPN transistors Q1-Q3 within the control box, via the 6-wire cable and each relay has a coil back-EMF quenching diode.

When RLY2 switches on, it energises the motor start winding. When RLY1 is switched on, it reverses the polarity of this winding, so the motor will start spinning in the opposite direction. As its name suggests, the start winding is only energised when the motor is first started, hence the relay. After that, the start winding is disconnected so it doesn't burn out. The motor keeps spinning in the direction that it started.

RLY3 is used to energise the Run winding. You may wonder why this is necessary since the Induction Motor Speed Controller can be switched on and off. When the IMSC is switched off, it will slowly spin the motor down at the programmed ramp rate. By disconnecting the run winding from the IMSC, the lathe motor will spin down more rapidly and naturally, improving safety.

Three LEDs are also fitted into the box housing the Explore 100, labelled Reverse (yellow), Start (red) and Run (green). These are effectively wired in parallel with the three relay coils (via CON4), with 560Ω current-limiting resistors in series with each LED. These provide feedback on what the motor is doing.

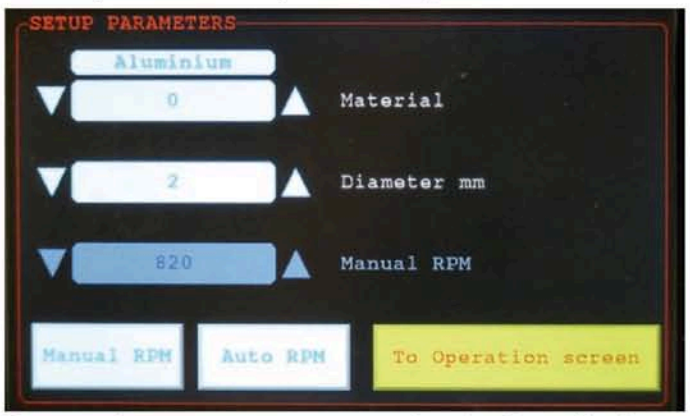
Speed Controller interface

Now turning our attention back to the control circuitry around the Explore 100 and the second Cat5 cable, this is wired to a small box attached to the side of the IMSC which provides an isolated interface to it. A small, separate circuit board labelled "output frequency sense" is fitted inside the IMSC enclosure. Let's take a look at this first.

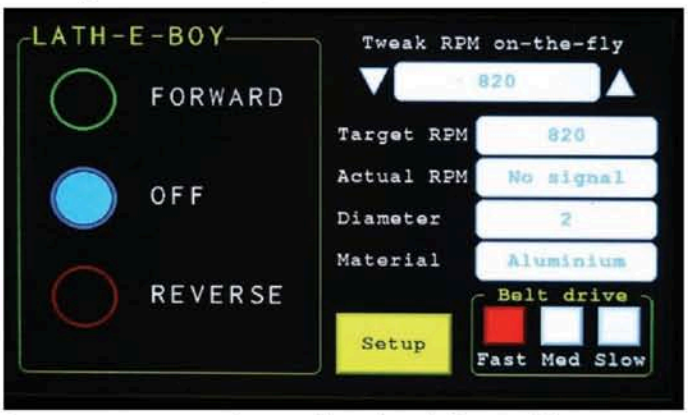
The IMSC, interface circuitry, relay box and plugpacks were mounted on the rear of the lathe stand, with the touchscreen controller box up on top.

This is connected across the U and W motor outputs which power the main "run" winding. The differential voltage between these outputs passes through an RC low-pass filter comprising two 5.1kΩ 1W (mains-rated) resistors and a 220nF X2 mains capacitor. This has a -3dB point of around 71Hz so it filters out the IGBT switching edges.

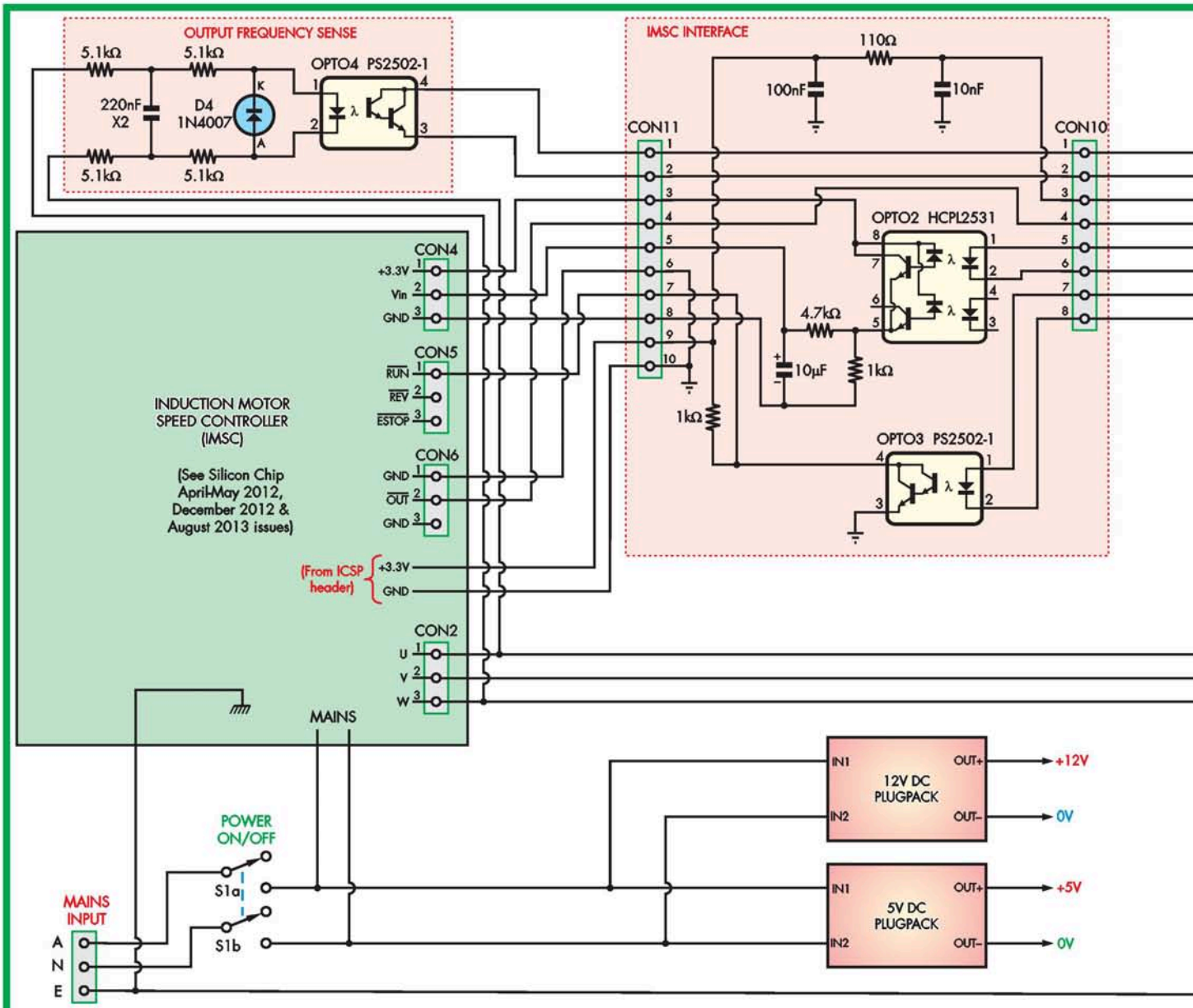
The resulting sinewave signal is then applied to the infrared LED within a PS2501 Darlington output optoisolator. D4, a 1N4007 diode



Screen1: the setup screen appears when the Controller is first powered on and allows you to set either the material type and diameter or the chuck RPM.



Screen2: once setup is complete, it switches to this screen where you can start, stop and reverse the motor, monitor chuck speed and tweak it if necessary.



LATH-E-BOY INDUCTION MOTOR CONTROLLER

Fig.1: circuit diagram of the Lathe Controller, with the Induction Motor Speed Controller (at left) and Explore 100 (centre right) circuits shown as "black boxes". See the relevant articles (referred to in text) for internal details. The additional circuitry ties these two modules together as well as providing motor speed feedback, safe motor starting and reversing, feedback-based speed control and status indication.

connected in inverse parallel with this LED prevents it going into reverse breakdown for one half of the output phase. This means that the output of the optocoupler is switched on to produce one pulse for each AC cycle fed to the motor.

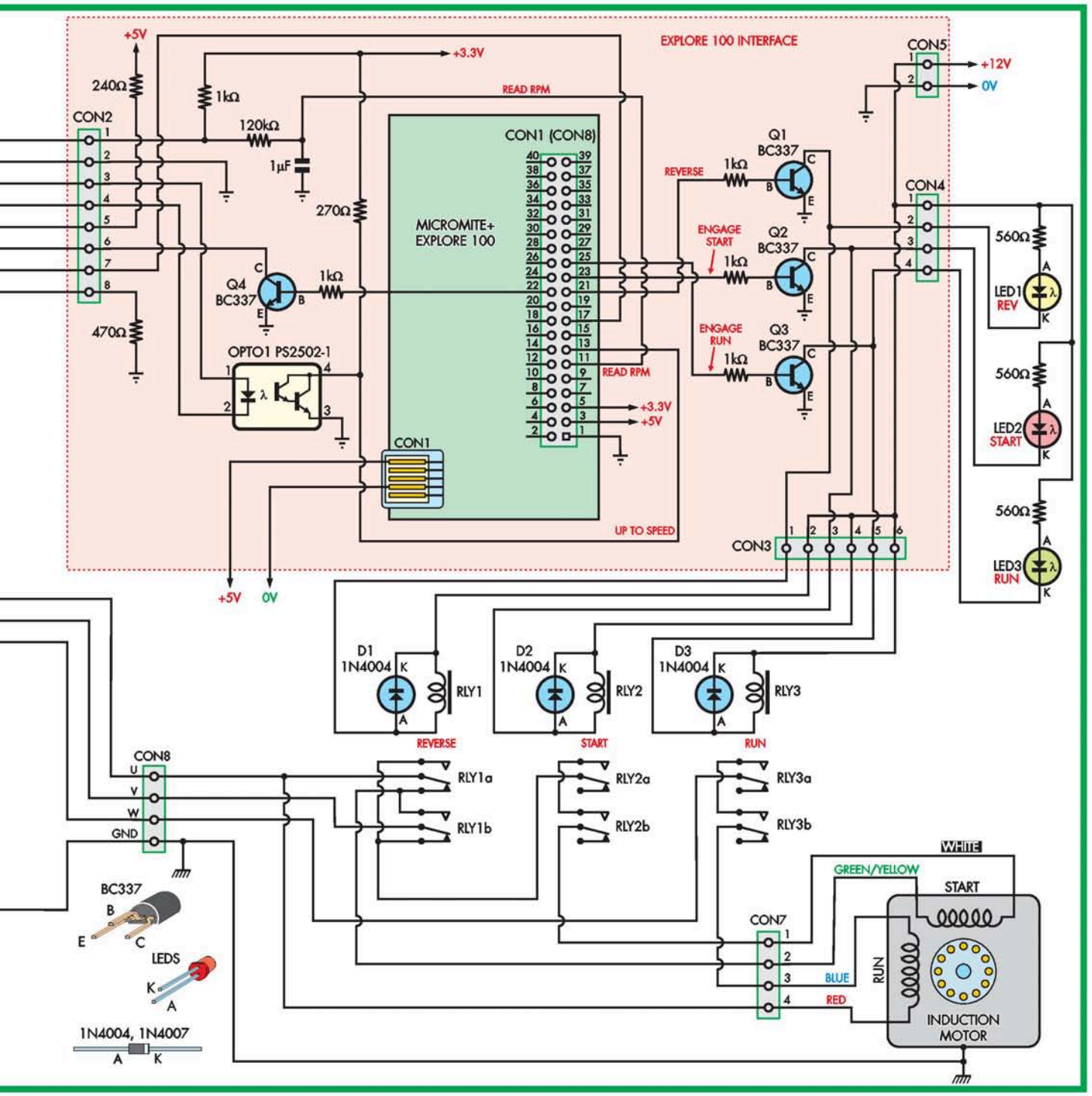
The two extra 5.1kΩ resistors limit the LED current to around 17mA [350VDC(peak)÷(4 x 5.1kΩ)], which is well within the 80mA rating of the device.

The output pulses from the frequency sense circuit are fed right through the IMSC interface box and back to the Explore 100 unit via pins 1 and 2 of the Cat5 cable. One end of this signal is terminated to the Explore 100's local ground while the other has a 1.2kΩ pull-up resistor to the 3.3V rail, giving a 3.3V square wave signal.

This square wave is filtered using a 120kΩ/1µF low-pass filter, before being fed to pin 11 on the Explore 100 I/O header ("read RPM"). The PIC32 (Micromite Plus) in the Explore 100 can then count the number of pulses on this pin each second to determine the spindle speed. This RC filter has a time constant of 120ms which may seem quite long, with respect to the 50Hz waveform when the motor is running at full nominal speed, with a 50Hz output.

However, the filter has to cope with a pulse rate from 50Hz down to about 5Hz, so the 120ms time constant seems to be a reasonable compromise.

As well as measuring motor speed,



the Micromite also needs to be able to control the speed. This is done using the PWM output on pin 22 of the I/O header (CON1), which drives the base of NPN transistor Q4 via a 1kΩ current-limiting resistor. When Q4 is on, it pulls current through the upper LED in the HCPL2531 dual high-speed optocoupler within the IMSC Interface module (OPTO2).

Because the emitters of the two output transmitters are joined together, we're only using half of this device. The collector of the output transistor at pin 7 is connected to a 3.3V rail output from the Induction Motor Speed Controller while the emitter at pin 5 has a 1kΩ pull-down to the analog ground of the IMSC, resulting in a 3.3V square wave at pin 5 of OPTO2.

This passes through an RC low-pass filter of 4.7kΩ and 10µF, having a -3dB point of 3.4Hz. This smoothes the PWM waveform to produce a variable voltage that depends on the PWM duty cycle. The variable voltage is then fed to the control input (Vin) of the IMSC. The 3.3V and GND rails for this part of the circuit are connected only to CON4 on the IMSC so that digital noise on other pins does not unduly affect the analog control signal.

There is a second, Darlington output optocoupler within the IMSC interface (OPTO3) which drives the RUN-bar input at CON5 of the IMSC, enabling or disabling the motor output. A 1kΩ pull-up resistor to 3.3V sets the default state to have the motor switched off.

It only switches on when pin 7 on the Explore 100 I/O header goes high, allowing current to flow through the emitter LED within OPTO3. The LED current is set by a 470Ω resistor between this LED cathode and ground. When pin 7 goes high, OPTO3 switches on, pulling RUN-bar low.

The $\overline{\text{OUT}}$ terminal on CON6 of the IMSC is pulled low by the speed controller when the motor is up to speed. This is fed through the IMSC interface to arrive at pin 2 of OPTO1, the cathode of its internal emitter LED. The LED anode is connected to the 3.3V supply rail of the IMSC via a pi filter consisting of a 100nF capacitor, a 10nF capacitor and a 110Ω resistor which also acts as a current limiter.

Thus, when the motor is up to speed and $\overline{\text{OUT}}$ is low, 30mA will flow through this circuit, switching on OPTO1 and pulling its output pin 4 low. This is normally held high by a 270Ω resistor and this signal is fed to pin 13 of the Explore 100 I/O ("Up To Speed") so that it can be sensed by the Micromite.

Remaining circuitry

Earlier, we described how RLY1-RLY3 are used to start the motor spinning in either direction and then to allow it to continue to run. The coils of the three relays are driven by NPN transistors Q1-Q3 which are in turn controlled from I/O pins 21, 23 and 25 on the Explore 100. Each has a 1kΩ base current limiting resistor and a back-EMF quenching diode connected across the relay coil.

Indicator LEDs1-3 are connected in parallel with the relay coils, each with their own 560Ω current-limiting resistor.

So these LEDs light up to indicate whether the motor start or run winding is energised and to show which direction the motor is running.

The rest of the circuitry comprises the mains power supply and motor wiring. The 230VAC input plug Earth connects to the Earth terminals on the IMSC and the motor housing. Active and Neutral pass through a double-pole power switch and then onto the input terminals of the IMSC and two plugpacks. The 12V plugpack powers the relays while the 5V plugpack powers the Explore 100.

The rest of the circuitry draws power either from the regulated supply rails within the Explore 100 or the IMSC.

The three IMSC outputs are wired up to the terminals of relays RLY1-RLY3 and in some cases, directly to the motor terminals.

See the panel elsewhere in this article describing how the motor connections are made.

As mentioned earlier, two of the three motor drive outputs (U and W) are also connected to the Output Frequency Sense circuitry.

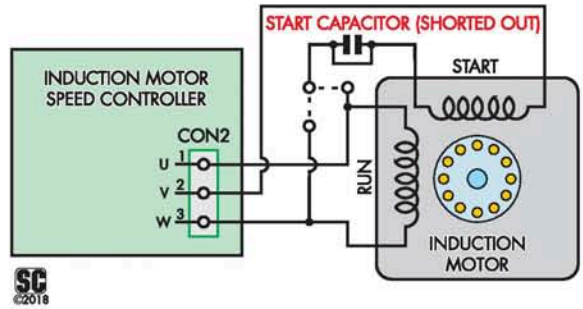


Fig.2: here's how the designer's lathe motor was wired up to the speed controller, ignoring the relays which control start-up and reversing, for the moment. The start capacitor is shorted out since it's no longer required. Note the two possible ways to wire up the one end of the start winding.

Software operation

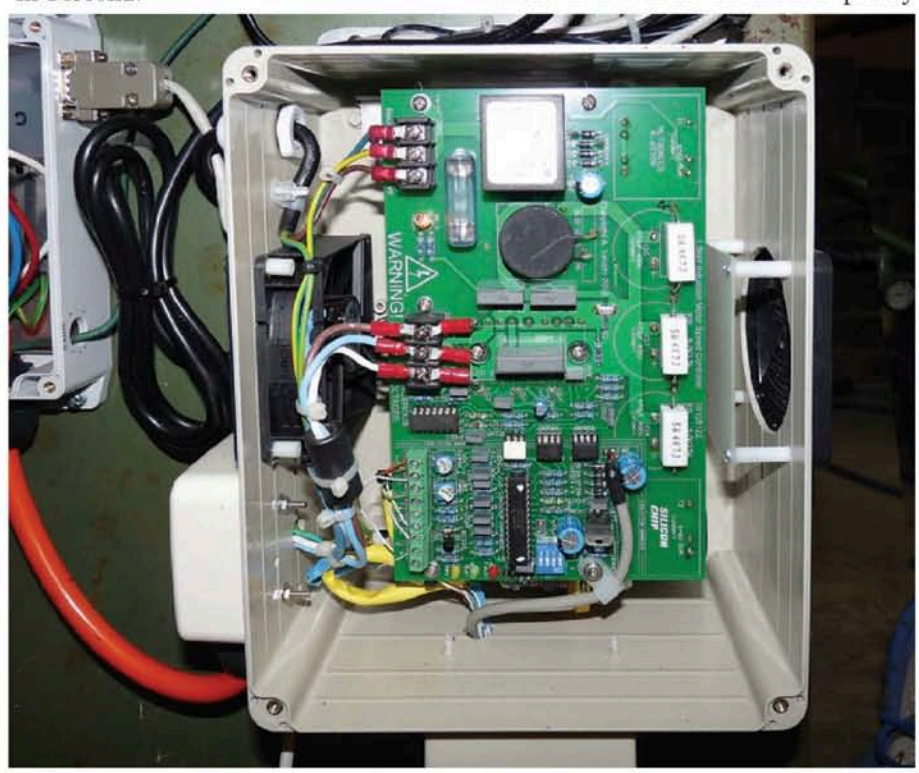
The main goal of this project was to have a supervisory control for the lathe, into which could be entered the material type and diameter to be turned. The software would then set the required speed and would control the lathe to maintain that speed, making the turning process much simpler. The Explore 100 with 5" touchscreen provides the ideal platform.

The set-up screen is shown in Screen1. It provides auto and manual RPM control modes. In auto mode, the user selects material and diameter and the controller does the rest. If manual mode is selected, the user sets the speed regardless of material and diameter. Once the selection has been made, the operation page is displayed, as shown in Screen2.

FORWARD, REVERSE and OFF are self-explanatory. The spinbox "Tweak RPM on-the-fly" allows the user to switch to manual mode and adjust the motor speed. Target RPM is the speed we want while Actual RPM is the inferred motor speed, based on the frequency measured at the motor controller output.

This is an excellent proxy for the spindle RPM, as verified with a temporary Hall Effect pickup on the tool post and a magnet on the chuck. The material and diameter selections are repeated on the Operation page.

The three square "radio" buttons in the lower right corner tell the software which of the three motor belt pulley



This shows the wiring between the IMSC and interface box. The speed feedback board is just visible below the main PCB. Note the improved ventilation.

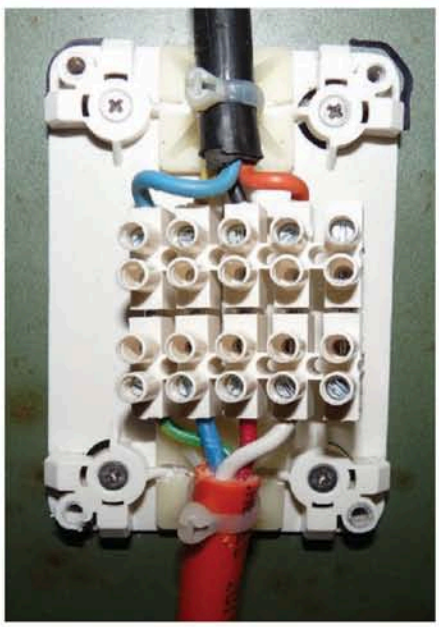
The pre-existing direction control switch box, which was wired to both motor windings.

positions is in use, as this affects the maximum and minimum RPM values. The lower speed pulleys are used only if additional torque is required at low speed.

(A radio button is like a checkbox except only one in a group can be selected at any given time.)

To ensure the software is responsive, pretty much all events are handled in interrupt routines, including the touchscreen interface, which utilises the TOUCH (REF) function. The motor speed is sensed by measuring the intervals between an interrupt triggered by the level change on the READ RPM input.

Motor speed control is achieved using a simple proportional feedback strategy. A closed loop continually measures the error and reduces it. Effective gain of this loop is controlled by selecting the time between corrections and the proportion of error applied to each correction.



This junction box connects the Controller outputs to the motor.

These numbers are determined by experiment and are quite flexible. Settling time and stability are completely adequate for the purpose. Since the source code is available, the software can be modified by those who would like to adapt it for their own projects.

The only niggle is the loading time of the title or "splash" screen. This takes nearly 12 seconds to load from the micro SD card.

Perhaps it should be called the "drip screen"! This is due to the way that MMBasic loads data off the SD card.

Parts list – Lath-e-Boy Lathe Controller

1 Induction Motor Speed Controller kit [Altronics Cat K6032]
1 Micromite Plus Explore 100 kit [Silicon Chip Online Shop SC3834 or from www.rictech.nz]
1 5-inch diagonal colour LCD to suit Explore 100 [eg, siliconchip.com.au/link/aaig or siliconchip.com.au/link/aaih]
3 10A 250VAC DPDT relays, 12V DC coil (RLY1-RLY3; [Jaycar SY4065])
3 DPDT relay cradles (optional, for RLY1-RLY3; [Jaycar SY4064])
2 10A mains cables, cut in half (for mains input and to connect plugpacks)
1 12V DC 500mA regulated plugpack
1 5V DC 1A regulated plugpack
1 10A 250VAC DPDT toggle switch (S1)
1 10-way connector with matching plug and cable (to connect IMSC interface to Speed Controller)
4 RJ-45 modular connectors
2 Cat5(e)/Cat6 cables with twisted pairs 1&2, 3&4, 5&6, 7&8
1 large solder type protoboard (cut up as required)
1 large jiffy box (for Explore 100 and associated components)
1 medium-sized jiffy box (for IMSC interface)
1 diecast aluminium box (to house RLY1-RLY3; must be earthed)
various lengths and colours mains-rated and light-duty hookup wire

Semiconductors
3 PS2502-1 Darlington optocouplers (OPTO1,OPTO3,OPTO4)
1 HCPL2531 dual high-speed optocoupler (OPTO2)
4 BC337 NPN transistors (Q1-Q4)
1 yellow 5mm LED (LED1)
1 red 5mm LED (LED2)
1 green 5mm LED (LED3)
3 1N4004 1A 400V diodes (D1-D3)
1 1N4007 1A 1000V diode (D4)

Capacitors
1 10µF 10V electrolytic
1 1µF multi-layer ceramic
1 100nF MKT or ceramic
1 10nF MKT or ceramic
1 220nF X2 MKP

Resistors (all 0.25W 1% unless otherwise stated)
1 120kΩ 4 5.1kΩ *(1W 5%)* 1 4.7kΩ 7 1kΩ 3 560Ω 1 470Ω 1 270Ω 1 240Ω 1 110Ω

Construction

You will need to build and test the Induction Motor Speed Controller and Explore 100 modules separately before you can build the extra circuitry which ties them together.

If you're building the IMSC from a kit, it should come with assembly instructions. Otherwise, refer to our articles in the April and May 2012 issues, plus the additional information and revisions in the December 2012 (siliconchip.com.au/Article/469) and August 2013 (siliconchip.com.au/Article/4219) issues.

For the Explore 100, assembly instructions are in the October 2016 issue; the only tricky aspects are solder-

Modifying the motor to allow the speed controller to be connected

It is worth reading the April 2012 article on the Induction Motor Speed Controller to get a background of induction motors and a description of the Controller. While its main purpose was to vary the speed of pool pumps, it was also suitable for the control of machine tools, such as lathes.

Most basic lathes vary the speed of the chuck by changing belts, an inconvenient and inefficient method of approximating the desired speed. As a result, it is likely that many hobbyist lathes remain on the one speed for most of their lives, a far from optimum situation for quality and speed of operation. Variable speed control is an attractive modification.

Any reasonably sized lathe will use a capacitor-start motor. This has a high starting torque to overcome the load presented by the belts, pulleys, close-fit bearings and back gears, with a centrifugal switch to take the start winding out of circuit as the motor comes up to speed. Unfortunately, the Induction Motor Speed Controller is specified as being unsuitable to drive such a motor. But is it?

The main reason given for the unsuitability is that at a low selected speed, the centrifugal switch will cut back in, and the current drawn by the start winding may burn the winding out. Almost as an afterthought, a sidebar advises that "there is also a risk that the over-current protection in the Speed Controller will simply prevent normal operation". Amen to that!

The subject of this project is a 1970's era Taiwanese lathe with a 250mm swing. Its motor is a ¾ horsepower (560W) four-pole capacitor start induction motor. It is also reversible.

At first glance, it appears well within the 1500W capacity of the Speed Controller. The main and start windings are brought out to the on-off switch, which reverses one winding to reverse the rotation of the chuck.

Having access to both ends of the start winding overcomes the problem of the centrifugal switch re-engaging at low revs. It is easy to provide a relay to isolate the start winding as the motor speed is reduced. It is also easy to provide a relay to reverse the polarity of the start winding so the motor will start forward or reversed as required.

Even with the start winding isolation and direction taken care of, the subject motor would not start, as the Speed Controller tripped out with a fault indication. Over current was a prime suspect. Certainly, the instantaneous current on starting is enormous – at 230VAC 50Hz, it is about 50A. Starting at low speed, which means low voltage as well, should alleviate this.

Although the Controller permits a slow ramp-up from a low voltage, at slow speeds the winding reactance drops proportionately to the frequency, so the current does not necessarily drop as expected. This motor simply drew too much current for the Controller to start it.

There is also a possibility, as yet unverified, that with a capacitor in circuit, the Controller interprets a leading power factor as a short circuit, since in both cases it would see current increasing without a corresponding voltage increase.

Fortunately, the Controller itself provides the solution. It has a three-phase output. We can split the windings across two phases to keep each phase current within the maximum of the Controller, at least up to a certain size of motor. One phase is selected for the main winding. Of the other two phase voltages, one leads the main by 120° and the other lags by 120°.

Either of these should give sufficient quadrature current to the start winding to create a rotating field but it is necessary to remove the start capacitor and short its connecting leads together. If the output terminals of the Controller are labelled A, B, and C, the main winding is connected between A and C and one end of the start winding is connected to B.

The other end of the start winding can be experimentally connected to A, then to C. The better of these options is typically the one that starts to turn the motor at the lower voltage. It does not matter whether the motor starts in the forward or reverse direction. The direction of rotation can be controlled with the forward/reverse relay or a winding polarity reversal.

Fig.2 shows the connection of the motor to the Controller in this case.

I found that this ¾ HP motor had to be accelerated with about a four-second ramp from 0-50Hz. This is set by trimpot VR2 (RAMP) in the Controller. As the voltage is applied and the armature begins to rotate, it generates a back-EMF that reduces the current and gives room for more voltage to be applied, accelerating the armature further. The ramp voltage must not increase too fast for the armature to accelerate and generate the current limiting EMF.

Other motor configurations

But what if both ends of the windings are not brought out, as is typical of a huge number of small, non-reversible capacitor start induction motors? Can such a motor still be controlled in the manner described above?

The answer in many cases is yes! Not only can such a motor be speed controlled, it can also be reversed. Fig.3 shows the two most likely motor configurations at left. In both cases, the start capacitor is removed and the wire that connects directly to one of the existing terminals is taped off and secured. The remaining wire is the new connection point for the start winding.

This wire, adequately insulated, is brought out of the capacitor chamber. This lead and the previously assigned phase and neutral leads connect to the three-phase output of the Speed Controller, as shown at right. Reversal of the direction of rotation is achieved by swapping any two phases.

Changing a faulty start capacitor is routine maintenance on induction motors, hence, removing the start capacitor and installing the two-phase wiring should be well within the capability of any builder with the knowledge and skill to build the Controller.

Doing so opens up a greatly increased number of applications for variable speed operation.

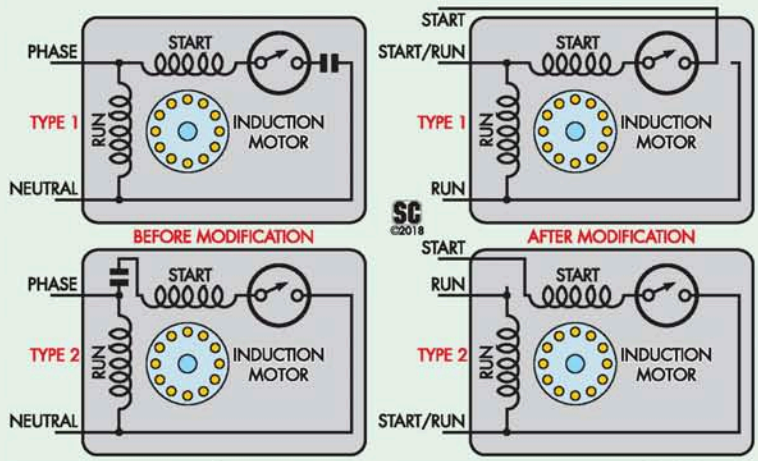


Fig.3: for motors where separate connections are not provided for the start winding, the start capacitor can be removed and one of its connections brought out to provide the connection to the start winding.

The relay box, which connects the IMSC to the motor, has an earthed aluminium backplate. If using a 3-phase motor, only two relays are required.

Using it with a 3-phase motor

While this project was designed to be used with a lathe driven by a single-phase induction motor, the IMSC is capable of driving 3-phase delta-wound motors.

Since a 3-phase motor lacks a start winding, start capacitor and centrifugal switch, you don't need RLY1 or RLY2 and their associated wiring. RLY3 will need to be a four-pole type to allow it to switch all three phases.

However, the design as presented here does not drive the "$\overline{\text{REV}}$" terminal on the IMSC so it has no way of commanding motor reversal for a 3-phase motor.

Therefore, you would need to run a connection between the collector of Q1 and the $\overline{\text{REV}}$ terminal on the IMSC so that the Explore 100 can reverse the motor direction. The software should not need any modifications.

ing the few SMDs. After that, it's pretty much just a matter of soldering the components in place where indicated on the PCB silkscreen.

The prototype Speed Controller interface was built into a small Jiffy box which was mounted to the outside of the IMSC, while the Explore 100 interface plugged directly into the Explore 100. As you can see from the photo, the "output frequency sense" section of the circuit was mounted inside the IMSC box itself.

The Explore 100 Interface, IMSC Interface and Output Frequency Sense sections of circuitry were built on solder-type prototyping boards using point-to-point wiring, so there are no PCBs or overlay diagrams. The relays were mounted in a separate box with an earthed aluminium backplate, as shown in the photo above.

Since each section of the circuit is relatively simple, after soldering the required components to a piece of protoboard, you should be able to use the circuit diagram as a guide to wiring it up. You can use wire wrap wire (Kynar), bell wire or light-duty hookup wire to make the connections between component pins.

The Explore 100 and its associated interface components, shown in the shaded box in Fig.1, were housed in a single large jiffy box. You will need to make a rectangular cut-out in the lid for the Explore 100's LCD plus three holes for the status indicator LEDs and some holes for wires/sockets for the DC power input and RJ-45 (or DB9, as in the prototype) interface sockets.

Loading and using the software

If you've built The Explore 100 kit should come with a pre-programmed microcontroller but you still need to set up the LCD panel and then load the Lathe Controller BASIC code into the Explore 100.

You should do this with the IMSC and related circuitry powered down, however, the circuit has been designed so that nothing bad should happen if the unit is powered up without any code running on the Explore 100.

In other words, the default state of each output is set up to be safe and not drive anything, including the motor.

Instructions for setting up the LCD panel and touchscreen were given in the October 2016 issue (Explore 100 part 2; **siliconchip.com.au/Article/10303**), however, if you don't have that handy, you can simply enter the following commands over the serial or USB console:

```
OPTION LCDPANEL SSD1963_5,LANDSCAPE,48
OPTION TOUCH 1, 40, 39
GUI CALIBRATE
```

After typing the final command and pressing enter, you will be presented with a cross-hair target in the corner of the LCD screen.

Press on its centre with a stylus-type object (eg, a toothpick) and then repeat for the targets which appear in the other three corners. With any luck, you will get a message on the console which reads "Done. No errors" and that indicates that the touchscreen has been set up correctly.

You can then download the Lathe Controller BASIC code from the SILICON CHIP website (free for subscribers) and upload it using MMEdit or similar software (MMEdit is a free download for Windows or Linux; see **www.c-com.com.au/MMedit.htm**).

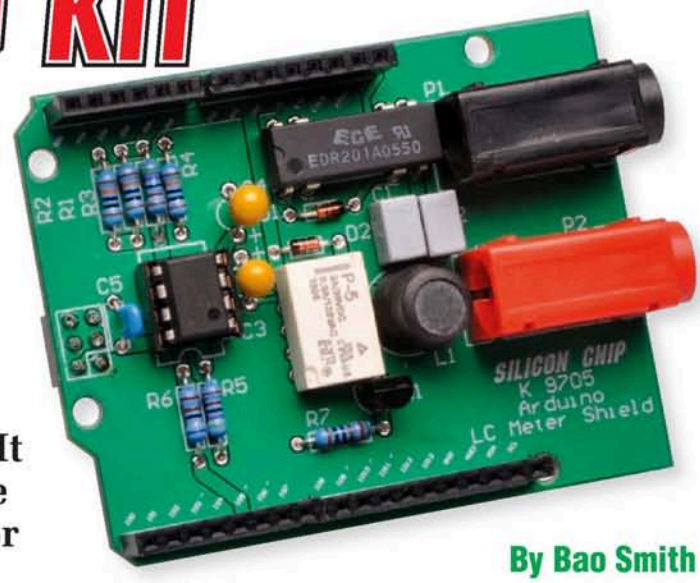
Once the code has been uploaded, MMChat should automatically launch and you can then issue the "OPTION AUTORUN ON" command, followed by "RUN" and the graphical user interface (GUI) should appear on the LCD screen.

You can verify that this appears to be working before disconnecting your PC and you are then ready to power the whole rig up and test it out properly.

We suggest you do this initially with nothing in the lathe so that you can verify it's all working correctly without risking any damage.

The operation of the software was explained earlier, although it's pretty much self-explanatory anyway. SC

THE ALTRONICS ARDUINO LC METER SHIELD KIT



Altronics have just released a complete shield kit based on Jim Rowe's Arduino LC Meter from the June 2017 issue (siliconchip.com.au/Article/10676). It includes all the parts needed to build it on a custom shield for Arduino, which makes building it that much easier. It even has the ability to auto-calibrate and detect if you have an inductor or capacitor connected.

By Bao Smith

This Altronics kit (Cat K9705) comes with everything you need to build a standard-sized Arduino shield (70 x 54mm) which incorporates all the functions of the Arduino LC Meter.

The kit is sold for $26.95 and the only parts that aren't included are the Arduino itself and an enclosure to put it in.

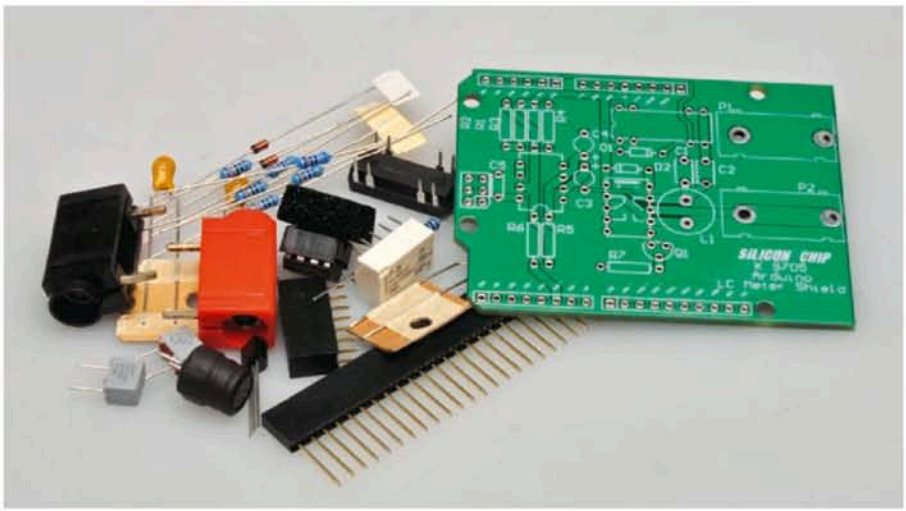
The new feature of this kit, mentioned in the introduction, is automatic detection of the type of component being tested. Jim's design for the LC Meter included a toggle switch to select between inductance and capacitance measurement modes.

The Altronics shield uses a relay instead, under control of the Arduino, and it automatically detects when it needs to switch modes to suit the component you have connected across the test terminals.

To make construction easier and the final result a bit more streamlined, the Altronics shield also uses a different approach to calibration. Rather than providing a switch and link to make fine tuning adjustments, you can do this over the USB serial console, if necessary. Or you can skip that step and just use it with the default calibration which is normally pretty accurate.

You will want to put it in some kind of enclosure to make it handy to use (as well as making it look more professional).

You could build it into a jiffy box like Jim did in the June issue. Or you could put it into the spiffy instrument case that's supplied with the Altronics Mega Box kit that was described last month, with pre-cut holes for the LCD, USB/power supply and test terminals.



Shown above are all the parts that come with the LC Meter Shield. The resistor values are not marked on the PCB, so refer to the overlay diagram (Fig.2) for clarification. Newer versions of the board will have the resistor values printed.

Circuit changes

The shield circuit diagram is shown in Fig.1. This also shows how it interfaces with the Arduino. If you compare this to our original circuit on page 30 of the June 2017 issue, you will see that there are two main differences.

Firstly, this shield does not include momentary toggle switch S3 or calibration link LK1 from the original design. As mentioned above, calibration is performed via the serial interface from a PC instead, saving on the cost and the space required for those components.

The other difference is that DPDT toggle switch S1, which was used to switch between inductor and capacitor mode, has been replaced by DPDT

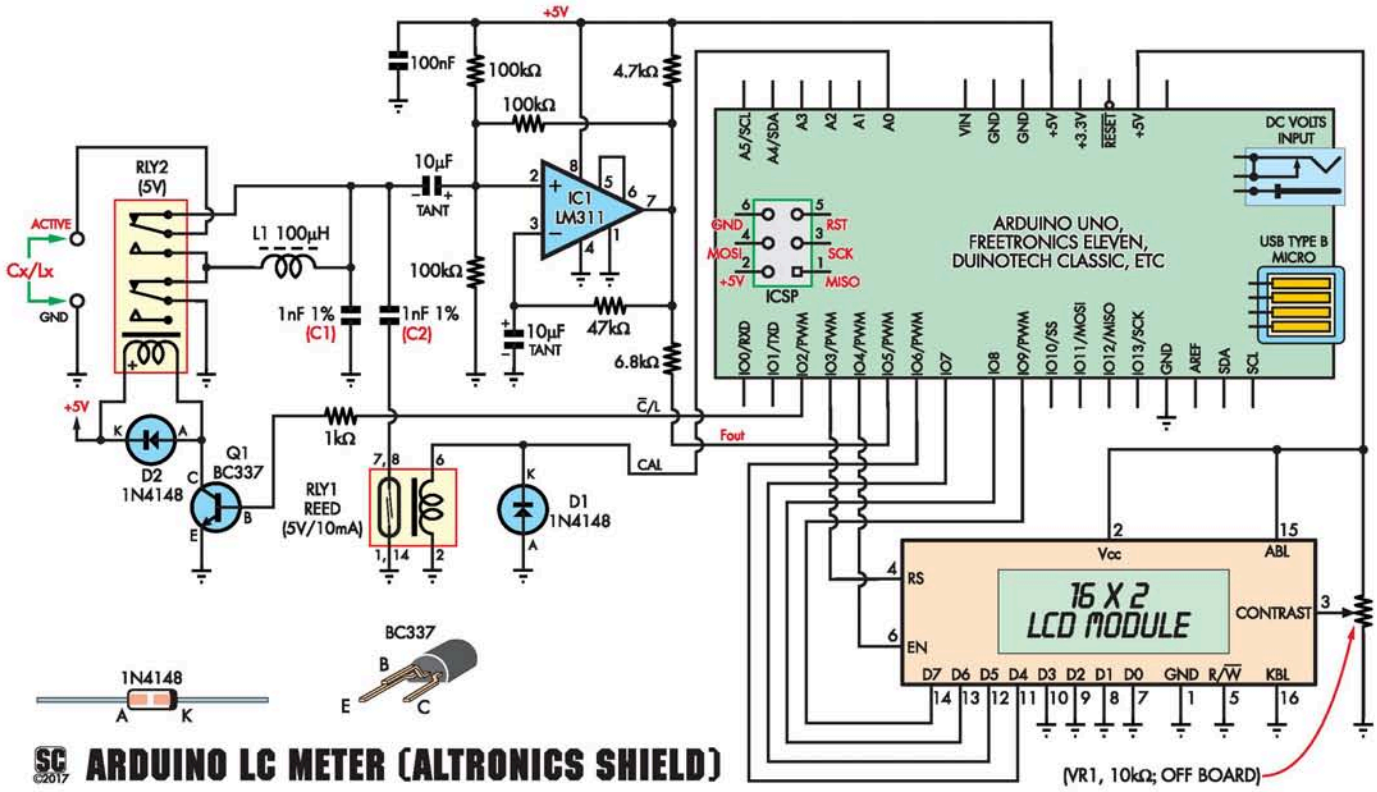


Fig.1: complete circuit diagram for Altronics' LC Meter Shield. The LCD module is hooked directly to the shield, compared to using the I²C serial module shown in the original June 2017 article.

relay RLY2, as mentioned earlier. RLY2 is driven by NPN transistor Q1 and has its coil back-EMF quenched at switch-off by diode D2.

Because the switch is now activated by the Arduino, there's no need for the Arduino to sense the position of this switch. In fact, input pin D2, which was used previously to sense the position of the switch, is now an output which drives transistor Q1 to energise the relay when measuring inductance.

The basic operation of the circuit is still the same; the resonant LC network formed by L1 and C1 is driven by an inverter built around high-speed comparator IC1 and oscillates at a frequency dependent on the values of those components.

The DUT is connected either in parallel with C1 (if it's a capacitor) or in series with L1 (if it's an inductor) and the shift in oscillator frequency is used to calculate and display the component value.

The final difference you will notice is that the Altronics design does not require the alphanumeric LCD to have an I²C interface module attached. It instead drives the LCD module using the standard old 4-bit parallel interface.

Again, this saves you a little money and time and it's possible because the Arduino has plenty of free pins to drive the display in parallel mode. It does require a few more wires to be run but it isn't hard, as you will see.

Only a small change to the program was necessary to allow this and you could change it back if you really wanted to use a serial LCD instead.

Construction

The biggest advantage of using the Altronics shield kit, besides not having to collect all the parts yourself, is that you don't have to do as much wiring since the PCB connects up all the components for you.

You just need to solder the supplied components onto the PCB, plug it into your Arduino, wire up the LCD, program it and away you go.

While all the supplied components are through-hole, a fine tip solder iron will help as some of the pins are a bit close together.

Use the overlay diagram, Fig.2, as a guide to mounting the components. Start by fitting the low-profile components first (ie, the resistors and diodes). Be careful with the orientation of the diodes; they face in opposite directions, so pay attention to Fig.2 and the PCB silkscreen.

We also recommend that you check the resistor values with a multimeter before fitting each one.

Solder the two 1nF MKT capacitors (C1 & C2) next. We found they were a little too wide to fit flush to the board but you can bend the pins slightly to help them fit.

We have been told by Altronics that the next batch of PCBs will fix this, but it's not a big problem.

Follow by mounting the single 100nF multi-layer ceramic capacitor (C5). The MKT and ceramic capacitors are not polarised.

Next, solder the two relays and the IC socket. All three must go in the right way around, as shown in Fig.2. BC337 transistor Q1 should be fitted next; note that it is mounted quite close to the adjacent relay but it will fit.

It's then time to solder in the four long-pin headers, with the long pins poking out through the underside of the shield board. This is a little fiddly since you need to solder around the bases of the pins but it isn't too hard if you use decent solder.

You can also solder the 2x3 dual-row pin header at this point; it's the only component that's mounted on the underside of the board, with the pins soldered on the top side.

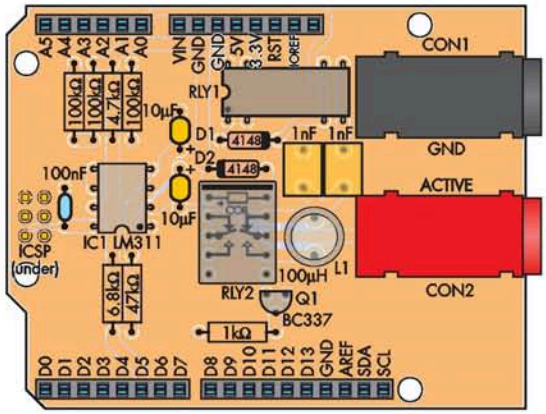


Fig.2: PCB overlay for the LC Meter Shield from Altronics. Take care to note orientation of the components when applicable, and the values of the resistors as they aren't marked on the board. Make sure to not confuse the 47kΩ and 4.7kΩ resistors as their colour band codes are quite similar.

Finally, fit the two tantalum electrolytic capacitors (C3 & C4) and inductor L1. Take care with the orientation of the capacitors since it is critical; the printed label on the capacitor body will have a + sign indicating the positive lead and this must be soldered to the positive pad as indicated in Fig.2.

In other words, the capacitors should be soldered with their positive leads facing in towards each other.

Check your soldering carefully, then plug IC1 into its socket (being careful not to bend any of its leads underneath the IC) and you are ready to plug the shield into your Arduino board.

Before you can program it, though, you will need to attach the LCD panel. Unlike Jim Rowe's version of this project, this one does not use an I^2C adaptor for the LCD.

So rather than having four wires, two for the power supply and two for the I^2C bus (SDA/SCL), this one requires all sixteen pins of the LCD module to be wired up.

However, because it's being driven in 4-bit mode, about half of them are connected to ground.

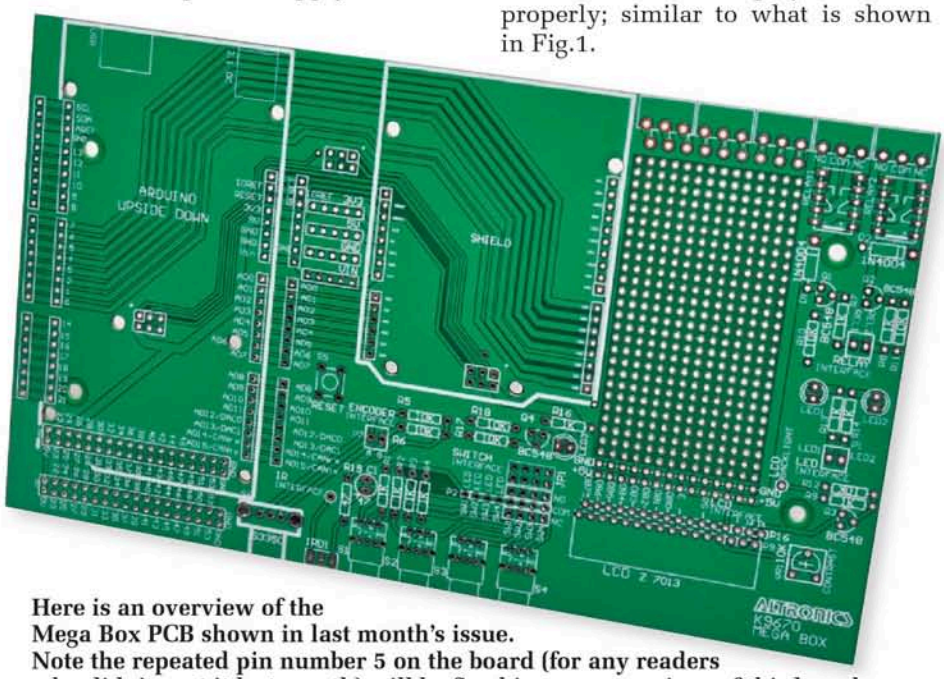
The required connections are shown in the circuit diagram; the final software may change some of these pins, so double check that your pin connections agree with the software.

Fitting it in the Mega Box

One thing to keep in mind is that if you are building this unit using the Altronics Mega Box described last month, a 10kΩ contrast adjustment trimpot is provided on the board.

The Mega Box also has pins 1 (GND), 2 (V_{CC}), 5 (R/W), 15 (BL+) and 16 (BL-) already connected.

If you're not using the Mega Box, these spare pins will need to be connected before the display will work properly; similar to what is shown in Fig.1.



Here is an overview of the Mega Box PCB shown in last month's issue. Note the repeated pin number 5 on the board (for any readers who didn't spot it last month) will be fixed in newer versions of this board.

Note though that pin 16 on the Mega Box is wired up to transistor Q3 and you will need to connect its base drive to +5V to enable the backlight.

Wiring up the LCD screen may seem daunting but all the other connections are taken care of by the shield, so once you have done this, you've almost finished.

The easiest way to wire the screen up is to use male/female jumper leads; the female end can plug into the header on the LCD and the male plug goes into the relevant pin on top of the shield or Mega Box header.

Note that you can't easily run connections to the top of the shield in the Mega Box or the lid won't fit, as there just isn't enough clearance. So wire up to the headers provided on either side of the Arduino board instead.

The array of extra ground pins in the Mega Box will come in handy for connecting the unused LCD pins to ground.

Software

The software for this shield is a modified version of our LC meter code from the June 2017 issue.

For further details on its operation, refer to that article (see **siliconchip.com.au/Article/10676**).

Like the original firmware, you need to install two libraries before you can compile the software: FreqCount and LiquidCrystal_I2C. FreqCount is available from **www.pjrc.com/teensy/td_libs_FreqCount.html**

You also need the LCD and LiquidCrystal Arduino libraries if you don't already have them.

Having loaded the libraries and opened the sketch file in the Arduino IDE, plug your Arduino/Mega Box into your PC using a USB cable and upload the code.

Once loaded, the program should go through the initial calibration, the relays should click over and the LCD should start showing a reading.

You can then connect a capacitor or inductor between the test terminals and wait a couple of seconds and you should get a reading showing its value.

Using it

There are a couple of things you need to note when using this device and this applies to any L/C meter.

Firstly, the banana sockets make it convenient to plug in a pair of alligator clip leads and these are then easy

to clip to the leads of the component you want to test.

But keep in mind that such leads will have some capacitance (a few tens of pF, depending on how close together they are) and some inductance (maybe as much as 1µH).

So to accurately measure a small capacitance, make a note of the reading before and after connecting the clip leads to the test capacitor and then subtract the stray capacitance from the reading.

To accurately measure inductance, connect the alligator clips together, read off the inductance, then connect them to either end of the test inductor and subtract the earlier (stray inductance) reading.

If making a direct connection to the test socket, simply touching the test component leads to the contacts on the sockets may not be good enough.

This could introduce enough resistance to throw the reading off. You need to make sure the component leads are pressed firmly into the test socket surface to get the best result.

Calibration

As stated above, the LC Meter Shield automatically calibrates itself the first time it is powered up. But if you need to make adjustments to the readings (eg, because you have a more accurate reference meter), you will need to do this using the serial console instead.

Parts List

1 double-sided PCB, coded K9705, 68.5 x 53.5mm
1 set of four Arduino stackable headers (1 x 10-pin, 2 x 8-pin, 1 x 6-pin)
1 2x3-pin dual-row female header (ICSP connector)
1 EDR201A0550 reed relay (RLY1)
1 2A 5V mini DIL relay (RLY2)
1 8-pin DIL IC socket (for IC1)
1 black PCB-mount banana socket (CON1)
1 red PCB-mount banana socket (CON2)

Semiconductors
1 LM311P high-speed comparator (IC1)
1 100µH inductor (L1)
1 BC337 transistor (Q1)
2 1N4148 diodes (D1,D2)

Capacitors
2 10µF 25V tantalum electrolytics (C3, C4)
1 100nF multilayer ceramic (C5)
2 1nF±1% MKT/MKP (C1,C2)

Resistors (all 0.25W, 1% metal film)
3 100kΩ (R1,R2,R4)
1 47kΩ (R5)
1 6.8kΩ (R6)
1 4.7kΩ (R3)
1 1kΩ (R7)

Once you've uploaded the code to the Arduino from the IDE, you can open the serial console by using the CTRL+SHIFT+M key combination.

You can perform calibration with either an inductor or capacitor but you must accurately know its value. Before connecting it up, measure the stray inductance or capacitance of your test set-up, as described above, and compensate for it.

This means adding the stray capacitance/inductance measured before connecting the component to its known value.

Now connect it up and wait for the reading to stabilise. If it's exactly right, you don't need to do anything.

Otherwise, in the serial console, enter:

calibrate xxx.xxpF/nH

Here we used the Altronics LC Meter with alligator leads to measure a 150nF±10% capacitor, our Agilent LCR meter recorded exactly 150nF for the capacitor. The leads by themselves measured roughly 30pF.

Here is the Altronics LC Meter reading a 200µH toroidal inductor. In comparison, our Agilent LCR meter read an inductance value of approximately 204µH. Overall, not too bad considering the difference in price of the two pieces of equipment.

in the place of xxx.xxpF/nH, enter the value you computed above. For example, if your component is 1.01nF and you measured 23pF of stray capacitance, you would use "calibrate 1033pF" while if you have a 10.7µH inductor and measured 300nH of stray inductance, enter "calibrate 11000nH".

You should get a confirmation on the console and the reading on the display should then update to be the correct (computed) value.

That completes calibration.

Accuracy and drift

We found our uncalibrated test unit to be within a few percent of the error value for numerous components that we tested, compared to the readings on an Agilent LCR meter.

We believe some of this discrepancy is due to the fact that component values can vary depending on test frequency and the Agilent meter uses a lower test frequency than the Arduino LC Meter. Varying the test frequency on the Agilent LCR meter would often cause the result to change.

As some readers have pointed out, LC meters based on this design will drift as they warm up.

The June 2017 article suggested rebooting the unit prior to taking subsequent measurements, which does help as it gives it a chance to re-read the "no test component" oscillator frequency.

Drift is almost entirely due to changes in the behaviour of the LM311 comparator as it heats up from its own dissipation (power consumption).

The other solution is to leave the meter running for some time before using it so that its temperature has stabilised.

What could be improved?

We have some ideas as to how to compensate for this temperature drift but they require a more complex circuit. We may present an update at some point in the future, should we come up with a meter design that eliminates (or mostly eliminates) drift in the readings.

An example could involve using a thermistor or similar to monitor temperatures and then adjust the relay. Alternatively, we could repeatedly switch the device under test in and out of the circuit and measure the oscillator frequency shift, although that would require more complex circuitry.

On the functionality side, if you're using the Mega Box with the LC Meter there is some direct functionality that isn't easily accessible.

As it stands, you can only calibrate via the serial console, or let the software handle it automatically. However, with the Mega Box the rotary encoder could be used to handle nudging the calibration value similar to how the SPDT momentary switch was used in the June 2017 project.

Then one of the other pushbuttons could be used to zero out the calibration value, which can be helpful in dealing with any drift.

This requires software changes, but they shouldn't be too difficult. SC

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	3	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown

Fun for kids of all ages

KELVIN, THE *VERY* CLEVER CRICKET

See SILICON CHIP October 2017

Fun to build and fun to use: Kelvin can accurately tell the temperature and chirps it to you (in cricket code) while he flashes his eyes! You can build Kelvin in just an hour or so!

View online at siliconchip.com.au/Article/10828

Special pre-cut PCB plus programmed micro available from the SILICON CHIP online shop: www.siliconchip.com.au/Shop

POST XMAS TECH SALE

HUNDREDS OF SPECIALS IN-STORE OR ONLINE

Jaycar Electronics

SAVE UP TO $100

FROM $449

SAVE UP TO $100

PURE SINE WAVE INVERTERS WITH SOLAR REGULATORS

Perfect for off-grid solar power system in caravans, yachts, holiday houses and where inverters are used. Connect a solar panel directly to charge the connected battery. 12VDC.

600W 20A SOLAR REGULATOR MI-5720 **WAS $499 NOW $449 SAVE $50**
1000W 30A SOLAR REGULATOR MI-5722 **WAS $599 NOW $549 SAVE $50**
1500W 30A SOLAR REGULATOR MI-5724 **WAS $799 NOW $699 SAVE $100**

SAVE UP TO $50

FROM $79.95

SAVE UP TO $50

SEMI FLEXIBLE SOLAR PANELS

Ideal for mounting to curved or other irregular surfaces such as an RV roof or boat. 12VDC.

15W ZM-9149 **WAS $99.95 NOW $79.95 SAVE $20**
30W ZM-9151 **WAS $169 NOW $129 SAVE $40**
80W ZM-9153 **WAS $269 NOW $219 SAVE $50**

UP TO 30% OFF

FROM $59.95

SAVE $10

4K UHD

HDMI SWITCHERS

High performance, supports all 3D TV formats in addition to all HDTV formats up to 4K UHD. Includes remote control.

3 INPUTS AC-1760 **WAS $69.95 NOW $59.95 SAVE $10**
5 INPUTS AC-1762 **WAS $99.95 NOW $89.95 SAVE $10**

NOW $49.95

SAVE $25

HDMI EXTENDER

AC-1730 **WAS $74.95**

Extend your HDMI signal up to 30m using Cat5e/6 cables. Use your remote in either location with the built-in infrared transmitter.

NOW $179

SAVE $20

4K UHD

HDMI SPLITTER - 8 PORT

AC-1769 **WAS $199**

Allows you to send a single high definition HDMI signal to 8 separate target devices without losing audio or video quality. 8 outputs. Supports 4K UHD.

SAVE OVER $60

NOW $199

SAVE $66

2 X 100WRMS STEREO AMPLIFIER

AA-0470 **WAS $265**

Great sounding amplifier rated at a generous 100WRMS per channel. Built-in bass and treble controls. Multiple inputs. Remote control included.

- 420(W) x 135(H) x 214(D)mm

NOW $179

SAVE $40

9" HIGH RESOLUTION LCD MONITOR WITH HDMI INPUT

QM-3874 **WAS $219**

Ideal monitor solution for security, reversing or multimedia entertainment display. Composite RCA and HDMI inputs.

- 240(W) x 163(H) x 26(D)mm

SAVE $40

SAVE $250

4 CHANNEL NVR KIT WITH 4 X 720P IP CAMERAS

QV-3132 **ORRP $799**

Easy to use network video recorder package with crisp and clear images from infrared LED cameras. Supplied with a 1TB HDD for recording up to 300hrs of continuous video.

NOW $549

SAVE $250

BASIC EXPERIMENTERS KIT FOR ARDUINO

XC-4285 **ORRP $79.95**

The entry point for learning and experimenting with Arduino®. Contains many parts to get you up and running including a duinotech Nano board, breadboard, jumper wires and plenty of peripherals.

NOW $49.95

SAVE $30

35% OFF

30% OFF

VALUED AT $114.85

$79.95

SAVE $30.90

RGB LED CUBE BUNDLE

A stunning piece of art-meets-illumination that you can build yourself. Features 64 individually addressable RGB LEDs arranged as a 4x4x4 matrix. Sleek white PCBs give the completed project an ethereal appearance that is sure to enchant all who behold it.

RGB LED CUBE	XC-4624	**$49.95**
ACRYLIC ENCLOSURE	XC-4625	**$19.95**
RGB LED DRIVER	XC-4498	**$44.95**

$149

SAVE $30.90

TOUCH SCREEN MONITOR AND PCDUINO BUNDLE

Included is a custom made 7" LVDS colour LCD with capacitive touch and resolution of 1024 x 600 PLUS a pcDuino v3.0 (full sized single board with LVDS connector to connect to LCD touch screen included). Wi-Fi built-in into the board.

PCDUINO V3.0 WITH WI-FI	XC-4350	**$89.95**
7" LCD TOUCH SCREEN	XC-4356	**$89.95**

SAVE OVER $30

VALUED AT $179.90

UP TO 50% OFF THESE BOARDS

NOW $14.95

SAVE $15

LILYPAD BOARD

XC-4620 **WAS $29.95**

Compact ATMega 32U4 based main board designed with portability in mind. A single chip handles main controller functions as well as USB connectivity.

NOW $24.95

SAVE $5

LEONARDO BOARD

XC-4430 **WAS $29.95**

Now you can have your DuinoTECH Lite emulate a computer keyboard, mouse, joystick and many other types of input device.

NOW $139

SAVE $30

STEPDUINO BOARD

XC-4249 **WAS $169**

A complete, self-contained board perfect for building robots or other mechatronics projects. 2 x 4-wire stepper motor controllers. 1 x servo interface. 20 x 4 LCD.

SAVE UP TO $20 ON THESE SHIELDS

NOW $19.95

SAVE $5

EXPANDER I/O SHIELD

XC-4547 **WAS $24.95**

Expand the number of I/Os of an Arduino board.

- 16 inputs & outputs

NOW $39.95

SAVE $5

MIDI SHIELD

XC-4545 **WAS $44.95**

Add music instruments by giving your Arduino project a powerful MIDI communication protocol.

NOW $139

SAVE $20

WI-FI/ETHERNET WITH AIRPLAY/DLNA AUDIO XC-4548 WAS $159

A versatile shield that has both ethernet and Wi-Fi to give wired or wireless capability for audio streaming. Accepts music being pushed over Airplay for iOS devices or DLNA compatible devices including Android.

UP TO 20% OFF THESE MODULES

NOW $13.95

SAVE $3

8 X 8 DOT MATRIX DRIVER

XC-4532 **WAS $16.95**

Use this module to drive an 8x8 dot matrix display. Driven by shift registers it requires only three inputs, and a power supply.

NOW $19.95

SAVE $5

SI4703 FM TUNER BREAKOUT BOARD XC-4595 WAS $24.95

For the Silicon Laboratories Si4703 FM tuner chip capable of detecting and processing both Radio Data Service (RDS) and Radio Broadcast Data Service (RBDS) information.

NOW $19.95

SAVE $2

4WD DC POWER SUPPLY MOTOR DRIVER

XC-4460 **WAS $21.95**

This module is one for the robotics hobbyist or professional who needs 4WD with individual motor control. Motor Supply Voltage: 5-16VDC power supply. 1A current.

NOW $9.95

SAVE $7

FM RADIO SNAP-ON KIT

KJ-8978 **ORRP $16.95**

Create a fully functional selectable FM radio with this simple snap on kit. Requires 2 x AA batteries.

NOW $24.95

SAVE $3

12-IN-1 ELECTRICAL EXPERIMENT KIT KJ-8919 WAS $27.95

12 different experiments to construct that demonstrate various electronic principles. Ages 8+.

NOW $39.95

SAVE $10

24-IN-1 SNAP-ON SOLAR KIT

KJ-8987 **WAS $49.95**

Build up to 24 projects including a solar coloured lamp, hand crank fan and police siren. Ages 6+.

NOW $39.95

SAVE $10

LAMP CONSTRUCTION KIT KJ-8999 WAS $49.95

Retro do-it-yourself table lamp. High quality metal parts. Power from USB or 2 x AAA batteries.

ARDUINO® PROJECT OF THE MONTH

AN EASY WAY TO TEACH KIDS ABOUT ARDUINO

Linkers are like building blocks for Arduino, and with the set of parts here, you can build some simple circuits to demonstrate and learn about digital electronics. The simple plug design means even kids can help – no soldering needed and they only plug in one way.

Build a Blinking Light or a Slider Controlled Buzzer, and understand the basics of electronics. Kids can even learn to program using simple graphics drag-and-drop programming called ArduBlock.

KIT VALUED AT $108.50

NERD PERKS CLUB OFFER
BUY ALL FOR $74.95
SAVE OVER $30

DIY

MORE INFO ONLINE

SEE STEP-BY-STEP INSTRUCTIONS AT www.jaycar.com.au/ardublock

WHAT YOU NEED:

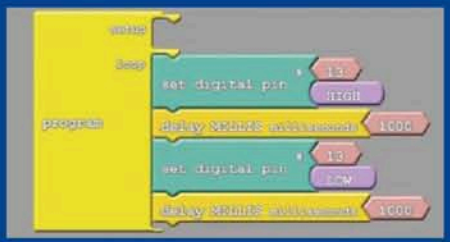
1 X UNO MAIN BOARD	XC-4410	$29.95
1 X LINKER BASE SHIELD	XC-4557	$24.95
3 X 200MM LINKER JUMPER LEAD	XC-4558	$4.95
1 X 10MM GREEN LED	XC-4565	$5.95
1 X 10MM RED LED	XC-4566	$5.95
1 X LINKER PUSH BUTTON SWITCH	XC-4571	$4.95
1 X LINKER SLIDE POTENTIOMETER	XC-4579	$15.95
1 X LINKER BUZZER	XC-4580	$5.95

SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

TECH TIP

PROGRAMMING MADE EASY WITH ARDUBLOCK:

ArduBlock is a graphical drag-and-drop type programming environment for Arduino®. Ideal for kids! By dragging and dropping colour coded blocks into the workspace, a fully functioning Arduino® program can be created easily!



15% OFF ALL LINKER MODULES

20% OFF ALL 3MM & 10MM LINKER LEDs

30% OFF ALL LINKER JUMPER LEADS

20% OFF

NOW $19.95
SAVE $5

LINKER BASE SHIELD

XC-4557 **WAS $24.95**

Allows simple and tidy connection between all Linker sensors/modules and Arduino/pcDuino.

NOW $39.95
SAVE $5

PC PROGRAMMABLE LINE TRACER KIT

KJ-8906 **WAS $44.95**

An educational introduction to the world of robotics and programming. Ages 12+.

NOW $29.95
SAVE $20

AIR POWER ENGINE CAR KIT

KJ-8967 **WAS $49.95**

A green powered car! No batteries or motors required. Operates entirely using air, and travels up to 80m on one single tank. Ages 10+.

NOW $29.95
SAVE $20

SOLAR POWERED ROBOT KIT

KJ-8966 **WAS $49.95**

Can be transformed into 14 different functional robots from the many different parts. Ages 10+.

NOW $18.95
SAVE $6

SALT WATER FUEL CELL ENGINE CAR KIT

KJ-8960 **WAS $24.95**

Demonstrate the concept of a salt powered automotive engine. Assemble, add salt water, and off the car goes! Ages 8+.

SAVE UP TO $30 ON THESE HOME THEATRE

NOW $19.95
SAVE $5

IN-LINE HDMI ESD PROTECTOR
AC-1738 **WAS $24.95**

Help protect a HDMI port against static shocks, surges and lightning strikes. HDCP compliant/EDID pass through.

NOW $89
SAVE $30

CAT 5 AV EXTENDER BALUN WITH IR REMOTE SENSOR
QC-3681 **WAS $119**

Transmit crystal-clear audio and video signals over long distances via Cat 5 cable. Signals transmitted up to 300 metres on UTP.

WIRELESS 2.4GHZ DIGITAL AUDIO SENDER
AA-2102 **WAS $109**

Uses a 34 channel frequency hopping transmission so you get seamless crystal clear audio. Up to 30m range. Includes two power & audio cables.

NOW $99
SAVE $10

SAVE $20 ON THESE PERSONAL AUDIO

STUDIO STYLE MICROPHONE
AM-4129 **WAS $99**

Speak, sing and record via USB. Great for podcasting, recording, Skype®, YouTube®, etc. Includes tripod stand.

NOW $79
SAVE $20

SINGLE CHANNEL WIRELESS UHF MICROPHONE
AM-4119 **WAS $99.95**

Great way to add a wireless microphone to any PA system. Provides XLR and 1/4" unbalanced outputs for use in any audio desk.

NOW $79.95
SAVE $20

RECHARGEABLE BLUETOOTH® SPEAKER
XC-5225 **WAS $99**

Bluetooth

High quality great sounding speaker to take anywhere. On-board playback control. 2 x 6WRMS output power. Recharges via USB. Cable included.

UP TO 35% OFF THESE VEHICLE ACCESSORIES

IN-CAR FM TRANSMITTER
AR-3127 **WAS $29.95**

Play music from your Smartphone through your car's sound system.

iPhone® not included

NOW $24.95
SAVE $5

NOW $24.95
SAVE $15

BLUETOOTH® IN-CAR EARPIECE WITH USB CHARGER
AR-3135 **ORRP $39.95**

Tiny Bluetooth® enabled smart device providing hands free communication. Includes cigarette lighter adaptor. USB 2.1A and 1A charging ports.

NOW $149
SAVE $20

UNDER SEAT ACTIVE 8" SUBWOOFER
CS-2286 **WAS $169**

Add some bottom end to your car audio. MOSFET output stage for low distortion and noise. Compact size fits under a seat. Ideal for utes, convertibles and trucks. 55WRMS power output.

SAVE UP TO $70 ON THESE PARTY EQUIPMENT

NOW $74.95
SAVE $10

9W GALAXY MAGIC LED LIGHT WITH DMX
SL-3484 **WAS $84.95**

A moving stage light with 9 different colour combinations and effects. Select between automated colour patterns, sound activator or DMX controlled. Ideal for stage lighting, club and party applications. Mains powered.

NOW $199
SAVE $70

DMX POWERED LASER BEAM
SL-3451 **WAS $269**

Create lasers at your next party, concert, or stage production. Features an XLR out plug that allows you to daisy-chain multiple units together for full DMX controlled ambience. Red, green & yellow lasers. Mains powered.

NOW $349
SAVE $30

PARTY LIGHT KIT WITH STAND AND CONTROLLER
SL-3469 **WAS $379**

This unit consists of a sturdy metal stand that deploys from 1.3m to a massive 2.15m. Supplied with 4 x PAR lights, mains (240V) connector, T-bar, stand, footswitch and carry bags. 910(L) x 242(H) x 48(D)mm.

NOW $59.95
SAVE $10

+FREE TRANSMITTER BATTERIES (AR-1823) VALUED AT $34.95

IR REMOTE CONTROL EXTENDER TO SUIT PAYTV AR-1821 **WAS $69.95**

Control a VCR, DVD/Blu-ray player, Hi-Fi and PayTV box (including most modern ones) from another room up to 30m away.

NOW $29.95
SAVE $10

CENTRE SPEAKER WITH BRACKET CS-2463 **WAS $39.95**

2 x 2.5" full range speakers rated at 15WRMS suits entertainment system set-up. Supplied with an adjustable swivel mount bracket for wall installations.

NOW $29.95 pr
SAVE $10

2.5" CUBE SPEAKERS
CS-2431 **WAS $39.95**

Stylish full range 15W speakers suits entertainment system or small PA set-up. Swivel brackets and mounting hardware included. Sold as a pair.

25% OFF THESE SPEAKERS

720P HD OUTDOOR WI-FI IP CAMERA

QC-3846 **WAS $149**

View what's going on with your Smartphone, from anywhere in the world. Equipped with IR LEDs for day/night use. P2P for easy set-up.

NOW $119
SAVE $30

8 ZONE WIRELESS ALARM KIT

LA-5280 **ORRP $129**

High quality home alarm with user-friendly features. Quick and easy installation. Can be controlled from Smart Panel or Keyfob remote control (included). 120dB+ internal siren.

NOW $99
SAVE $30

800TVL HIDDEN CAMERA IN PIR HOUSING

QC-8652 **WAS $99.95**

High quality camera disguised inside a housing that appears to look like a PIR. Mounting hardware included.

NOW $79.95
SAVE $20

SAVE UP TO $30 ON THESE SECURITY PRODUCTS

NOW $64.95
SAVE $15

USB 3.1 TYPE-C SATA HDD DOCKING STATION

XC-4672 **WAS $79.95**

Accepts 2.5" and 3.5" drives. Ultra high speed USB 3.1 up to 430Mbps transfer rates. Plug and play.

NOW $49.95
SAVE $15

2 PORT VGA KVM SWITCH WITH AUDIO

YN-8402 **WAS $64.95**

Share your keyboard, monitor, mouse, and USB devices between two different computers. Plug and play. No drivers required.

PC MONITOR DESK BRACKETS

Flexible design with adjustable tilt, swivel and rotation.

Fits most 13 to 27 inch flat-screen displays.

- VESA compliant

SINGLE CW-2874 **WAS $59.95**
NOW $39.95 SAVE $20
DUAL CW-2875 **WAS $79.95**
NOW $59.95 SAVE $20

FROM $39.95
SAVE $20

UP TO 30% OFF THESE COMPUTER ACCESSORIES

NOW $99
SAVE $30

STEELMATE CAR ALARM

LA-9003 **WAS $129**

Affordable car alarm that features voice feedback on alarm status and operational parameters such open doors etc.

See website for full contents.

Bluetooth

NOW $49.95
SAVE $20

OBDII ENGINE CODE READER

PP-2145 **WAS $69.95**

Plugs into OBD-II port and transmits speed, RPM, fuel consumption, etc via Bluetooth to your Smartphone.

NOW $49.95
SAVE $5

12V CAR VOLTAGE, ALTERNATOR & TEMPERATURE DISPLAY

XC-0117 **WAS $54.95**

Plugs into the car's cigarette lighter socket to display the car's battery voltage and inside temperature.

UP TO 25% OFF THESE AUTO PRODUCTS

SAVE $40

NOW $99
SAVE $40

2500 LUMEN LED TORCH

ST-3499 **WAS $139**

Super bright and fully rechargeable tough aluminium alloy torch for your next adventure, or outback journey. Multiple light modes. 244mm long.

NOW $129
SAVE $40

1500 LUMEN RECHARGEABLE

SL-2886 **WAS $169**

Mobile LED work lights for those who need lots of light without a mains connection. 30W 1500 lumen. IP65 rated. Cool white. Supplied with mains charger.

- 350(H) x 210(W) x 219(D)mm

HALF PRICE!

NOW $7.45
HALF PRICE!

250 LUMEN HANDHELD

ST-3271 **WAS $14.95**

Powered by 3 x AA batteries, puts out a huge amount of light with a good spread.

UP TO 50% OFF THESE WORKLIGHTS

SAVE $100

4 STAGE 40A DC TO DC BOOST CHARGER

MB-3690 **WAS $399**

Capable of taking an 8-16VDC input voltage and giving a stable, regulated 13.8V/14.4V output to give your auxiliary battery a full 100% charge. Output current is rated 40A to ensure a quick charge.

NOW $299
SAVE $100

FROM $199
SAVE UP TO $170

MODIFIED SINEWAVE INVERTERS

Run small electrical appliances from your car or truck battery. 12/24VDC to 230VAC electrically isolated.

1000W 12VDC MI-5112 **WAS $229 NOW $199 SAVE $30**
1500W 12VDC MI-5114 **WAS $459 NOW $349 SAVE $110**
2000W 24VDC MI-5116 **WAS $569 NOW $399 SAVE $170**

SAVE UP TO $170 ON THESE INVERTERS

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

NOW $199 SAVE $40 — 5
NOW $159 SAVE $40 — 3
NOW $24.95 SAVE $15 — 4
NOW $169 SAVE $30 — 1
NOW $44.95 SAVE $15 — 2
NOW $9.95 HALF PRICE! — 6

1. **60W ESD SAFE SOLDERING STATION** TS-1513 **WAS $199**
- Particularly suited to lead-free soldering
- Easy temperature setting
- Fahrenheit or Celsius temperature display
- Temperature range: 160°C to 480°C
- 130(W) x 170(H) x 240(D)mm

2. **8 PIECE SCREWDRIVER AND TOOL SET** TD-2031 **WAS $59.95**
- Quality rubber-moulded insulation for in-hand comfort
- VDE approved to 1000V
- Insulated right to the tip

3. **0-16VDC LABORATORY POWER SUPPLY** MP-3802 **WAS $199**
- Compact size, high current
- 30A max, variable output
- Overload and short circuit protection
- 148(W) x 162(D) x 62(H)mm

4. **BENCH VICE** TH-1766 **WAS $39.95**
- Made from hard-wearing diecast aluminium
- Vacuum base and ball joint clamp
- 75mm opening jaw
- 160mm tall (approx)

5. **VARIABLE LABORATORY AUTOTRANSFOMER (VARIAC)** MP-3080 **WAS $239**
- Heavy-duty steel housing case
- 500 VA (fused) rated power handling
- 0~260 VAC @ 50Hz output voltage
- 165(D) x 120(W) x 160(H)mm

6. **DESKTOP PCB HOLDER** TH-1980 **WAS $19.95**
- Hold PCBs of up to 200 x 140mm
- Adjustable angle
- 300(L) x 165(W) x 125(H)mm

SAVE UP TO $30 ON THESE CLAMP METERS

AUTO RANGING 400A AC
QM-1561 **WAS $69.95**
- Cat III 600V, 4000 count
- AC/DC voltages < 600V
- AC current < 400A
- Jaw opening 30mm

NOW $59.95 SAVE $10

TRUE RMS 3000A AC
QM-1568 **WAS $119**
- Cat IV 600V, Cat III 1000V
- AC current < 3000A
- Flexible "clamp" loop

NOW $89 SAVE $30

TRUE RMS 1000A AC/DC
QM-1566 **WAS $159**
- Cat III 600V, 6000 count
- AC/DC voltage < 600V
- AC/DC current < 1000A
- True RMS, min-max, bargraph and more
- Jaw opening 40mm

NOW $139 SAVE $20

HALF PRICE

PLUG REMOVAL TOOL
TD-2000 **WAS $14.95**
Allows you to insert or unscrew F-Type or BNC connectors that have been in-place for a while.
- Comfortable grip
- Carbon steel
- 255mm long

NOW $7.45 SAVE $7.50

NOW $29.95 SAVE $10

44 BIN WALL MOUNT
HB-6340 **WAS $39.95**
- Various tool holders
- Assorted bin sizes
- Flexible mounting configuration
- 1080(W) x 450(H) x 15(D)mm

16 BIN TABLETOP
HB-6341 **WAS $49.95**
- Magnetic strip for tools
- Plenty of storage
- No fuss setup
- 660(H) x 640(W) x 31(D)mm

NOW $39.95 SAVE $10

UP TO 25% OFF THESE STORAGE ORGANISERS

NOW $29.95 SAVE $5

MINI NON-CONTACT IR IP67 THERMOMETER QM-7218 **WAS $34.95**
Ultra compact. Celsius or Fahrenheit readings. Batteries and lanyard included.
- Measurement range: -33 - 110°C

NOW $29.95 SAVE $5

125MM PRECISION LONG NOSE PLIERS
TH-1885 **WAS $34.95**
Japanese made. Serrated jaws and strong grip. Insulated soft touch handles.

Coin not included.

NOW $24.95 SAVE $5

LARGE RARE EARTH MAGNETS
LM-1652 **WAS $29.95**
Made from NdFeB (Neodymium Iron Boron). Nickel coating. Sold as a pair.

NOW $19.95 SAVE $8

GOOT DESOLDERING TOOL
TH-1856 **WAS $27.95**
Japanese made. Large vacuum chamber for strong suction.

EXCLUSIVE CLUB OFFERS:

FOR NERD PERKS CLUB MEMBERS

WE HAVE SPECIAL OFFERS EVERY MONTH. LOOK OUT FOR THESE TICKETS IN-STORE!
NOT A MEMBER? Visit www.jaycar.com.au/nerdperks

NERD PERKS CLUB OFFER

3 FOR $25

HEATSHRINK TAPE - BLACK
WH-5659
25mm wide. 5m long.
RRP $12.95 EA
SAVE 35%

NERD PERKS CLUB OFFER

FREE 30M ALARM CABLE*

4-ZONE ALARM SYSTEM WITH 2 WIRE TECHNOLOGY
LA-5475
** WB-1591 valued at $21.95. Valid with purchase of LA-5475.*

ONLY $119

NERD PERKS CLUB OFFER

SAVE $100

8 CHANNEL 1080P AHD DVR
QV-3157 **WAS $549**

NOW ONLY $449

NERD PERKS **SAVE 15%**

15A POWER CABLE
WH-3054 **WAS $11.95 CLUB $9.95**
Tinned copper cable. Red. 10m.

NERD PERKS **HALF PRICE!**

MAGNETIC WORK MAT
TH-1867 **WAS $12.95 CLUB $6.45**
8 x 10 inches.

NERD PERKS **SAVE 15%**

DESKTOP POWER SUPPLY
MP-3242 **WAS $59.95 CLUB $49.95**
12VDC 5A. Fixed 2.5mm plug.

NERD PERKS **SAVE 25%**

WIRELESS 433MHZ RECEIVER MODULES
ZW-3102 **WAS $13.95 CLUB $9.95**
300bps to 10kbps data rate.

NERD PERKS **SAVE 20%**

USB3.0 SDXC/MICRO SD CARD READER
XC-4782 **WAS $16.95 CLUB $12.95**
Read and write at ultra-fast speeds.

NERD PERKS **SAVE 10%**

CCD CAMERA EXTENSION LEAD
WQ-7276 **WAS $34.95 CLUB $29.95**
10m long.

NERD PERKS **SAVE 25%**

3 PIN XLR TYPE TO RCA ADAPTORS
PA-3802 **WAS $9.95 CLUB $7.50**
High quality, metal construction.

NERD PERKS **SAVE 25%**

CIGARETTE LIGHTER BATTERY MONITOR
QP-2220 **WAS $19.95 CLUB $14.95**
8 - 28VDC.

NERD PERKS **SAVE 10%**

1/4W CARBON FILM RESISTORS
RR-1697 **WAS $16.95 CLUB $14.95**
850 piece.

NERD PERKS **SAVE 25%**

HEATSINK COMPOUND
NM-2012 **WAS $19.95 CLUB $14.95**
150g tube.

NERD PERKS **SAVE 10%**

QUICK CONNECT CRIMP CONNECTOR PACK 160 PIECES
PT-4530 **WAS $22.95 CLUB $19.95**

NERD PERKS **SAVE 25%**

SELF AMALGAMATING TAPE
NM-2826 **WAS $19.95 CLUB $14.95**
10m long.

NERD PERKS CLUB MEMBERS RECEIVE:

10% OFF

RACK MOUNT CABINETS*

**Applies to 19" Rack Mount cabinets, Swing Frame Rack Enclosures, Pro Grade 19" Rack Style Equipment Enclosures. Excludes accessories.*

YOUR CLUB, YOUR PERKS:
CHECK YOUR POINTS & UPDATE DETAILS ONLINE.
LOGIN & CLICK "MY ACCOUNT"*.

**Conditions apply. See website for T&Cs*

SAVE UP TO $100

GREAT PRODUCTS AT GREAT PRICES FOR YOU TO ENJOY!

NOW $49.95
SAVE $50

2 WAY DISPLAYPORT SPLITTER

AC-1755 **WAS $99.95**

Send identical signals to two monitors simultaneously. Compliant with VESA DisplayPort. Includes a mains power adaptor.

ALSO AVAILABLE:
2 WAY DISPLAYPORT SWITCHER AC-1757
WAS $99.95 NOW $49.95 SAVE $50

NOW $99
SAVE $50

4K HDMI TO VGA AND STEREO AUDIO CONVERTER

4K UHD

AC-1770 **WAS $149**

Convert digital 4K UHD HDMI video and audio signal from your Blu-ray player or computer to standard VGA and RCA stereo audio signal for connection with your older style CRT/LED/LED monitors or projectors.

NOW $349
SAVE $50

1080P HDMI WIRELESS AV SENDER & RECEIVER

AR-1915 **WAS $399**

Play your PayTV, DVD or Blu-ray player from different rooms without running cables. WI-FI 5G band. HDMI connection.

2 WAY ACTI VE PA SPEAKERS WITH BLUETOOTH®

Bluetooth®

CS-2470

Great sounding indoor and outdoor active stereo speakers, utilising powerful woofers and quality silk dome tweeters. Sold in pairs.

5" CS-2470 **WAS $249**
NOW $199 SAVE $50
6.5" CS-2472 **WAS $299**
NOW $249 SAVE $50

FROM $199pr
SAVE $50

TIME LAPSE HD VIDEO CAMERA WITH LCD VIEWFINDER

QC-8034 **WAS $299**

Create amazing time lapse videos in high definition. Includes 2GB SD (accepts up to 32GB) card that can be played back on a computer, media player or suitable TV. Battery or USB powered. 1.44" LCD screen.

NOW $249
SAVE $50

CHECK VIDEO ONLINE!

NIGHT VISION SCOPE

GG-2129 **WAS $349**

Ideal for seeing in dark places when a torch is unsuitable - night camping, viewing wildlife at night, fishing, hunting & surveillance.

- 3 x Magnification
- IR Illumination
- Requires CR123A Batteries (not included)

NOW $299
SAVE $50

$199
SAVE $100

50W SOLAR BLANKET

ZM-9166 **WAS $299**

Ultra portable and lightweight. Perfect for charging mobile phones and other devices. 12VDC. Includes solar controller & battery clamps.

- Folds into canvas bag

CURIE HEAT TECHNOLOGY SOLDERING STATION

TS-1584 **WAS $359**

An outstanding, fast, accurate 50W ESD safe soldering station from Thermaltronics. Curie Point technology brings the tip up to operating temp fast. Works with leaded and unleaded solder. Mains powered. 0.5mm chisel tip included.
155(H) x 110(W) x 92(D)mm.

ALSO AVAILABLE:
SPARE TIPS WITH HEATING ELEMENT FROM $29.95

$299
SAVE $60

See website for more details.

THERMALTRONICS

TERMS AND CONDITIONS: REWARDS / NERD PERKS CARD HOLDERS FREE GIFT, % SAVING DEALS, DOUBLE POINTS & MEMBERS OFFERS requires ACTIVE Jaycar Rewards / Nerd Perks Card membership at time of purchase. Refer to website for Rewards/Nerd Perks Card T&Cs. PAGE 2: ARDUINO Bundle Deal includes 1 x XC-4624, 1 x XC-4625 & 1 x XC-4498. PCDUINO Bundle Deal includes 1 x XC-4350 & 1 x XC4356. PAGE 3: Nerd Perks Card holders receive special price of $74.95 for Linker Project Kit (1 x XC-4410 + 1 x XC-4557 + 3 x XC-4558 + 1 x XC-4565 + 1 x XC-4566 + 1 x XC-4571 + 1 x XC-4579 + 1 x XC-4580) when purchased as bundle. PAGE 4: FREE Transmitter Batteries 1 x AR-1823 applies with purchase of AR-1821 IR Remote Control Extender. PAGE 7: Nerd Perks Card holders gets FREE 30m Alarm Cable (WB-1591) valid with purchased of LA-5475 4-Zone Alarm System. Nerd Perks Card holders receive 10% OFF on Rack Mount Cabinets applies to Jaycar 232A Metal Rack product category excluding accessories.

NEW STORE: PORT ADELAIDE

OPENING MID-JANUARY
85-91 Port Rd, Queenstown, SA 5014
PH: 1800 022 888

FOR YOUR NEAREST STORE & OPENING HOURS:

1800 022 888
www.jaycar.com.au

93 STORES & OVER 140 STOCKISTS NATIONWIDE

Jaycar Electronics

Head Office
320 Victoria Road,
Rydalmere NSW 2116
Ph: (02) 8832 3100
Fax: (02) 8832 3169

Online Orders
www.jaycar.com.au
techstore@jaycar.com.au

Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from Catalogue Sale 26 December - 23 January, 2018.

PRODUCT SHOWCASE

Need a BIG DC Power Supply? Emona can help you

If you need a very big, programmable DC power supply – up to 2MW and more(!) – talk to Emona.

They've just been appointed the Australian and New Zealand distributors for Magna-Power Electronics, a worldwide leader in programmable high output DC power supplies.

Magna-Power Electronics designs and manufactures robust programmable DC power supplies ranging from 1.25kW to 2000kW+. This extraordinarily high DC output range is unique amongst power supply manufacturers.

Magna-Power's products are used by thousands of customers worldwide, feeding power to national laboratories, universities, defence, utilities and a wide range of industrial sites.

Applications for Magna-Power's DC power supplies include aiding in the manufacture of electric vehicles, simulating solar arrays for development of inverters, steering magnets for particle accelerators, powering radar systems, driving traction controllers for locomotive development, or in universities for cutting-edge energy research.

Magna-Power Electronics products are made in the USA at the company's 6800m^2 headquarters in Flemington, New Jersey.

Contact:
Emona Australia Pty Ltd
78 Parramatta Rd Camperdown NSW 2050
Tel: (02) 9519 3933 (offfices in all capitals)
Website: www.emona.com.au/magna-power

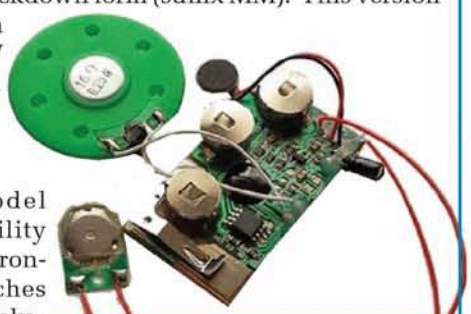
60 Second Sound Recording Module has a wide range of applications

KitStop's newly introduced KSSM-60S Sound module has double the storage capacity of the popular (but now superseded) KSSM-30S.

Other improvements in the KSSM-60S include a higher-rated battery set and a better sound from its on-board 16-ohm 40mm speaker. The latter extends the applications well beyond the talking greeting cards and gift boxes for which these modules were first designed.

Suggested applications for the KSSM-60S include sound effects for models, artworks, super hero costumes, science fair story-line delivery, DIY doorbells, nature sounds, point-of-sale alerts and add-ons to security sensors. Optional triggers for the KSSM-60S include tactile switches, micro switches, LDRs, reed switches, ultrasonic and PIR detectors, all of which are available from KitStop.

For a modest surcharge, model builders may purchase the KSSM -60S in a knockdown form (suffix MM). This version is supplied with an off-board 4.5V 3xAAA switched battery compartment and additional tactile switches.



This gives model makers the flexibility to mount the electronics, battery, switches and speaker remotely from each other.

Price of the KSSM-60S module is $7.77 including GST, plus pack and post.

Contact:
KitStop
PO Box 5422, Clayton Vic 3168
Tel: 0432 502 755
Website: www.kitstop.com.au

3D At Your Fingertips with Wacom Pro Pen

The new Wacom Pro Pen 3D, designed for use on a Wacom MobileStudio Pro, Cintiq Pro or the 2017 Intuos Pro Pen Tablet, brings intuitive creating, sculpting and designing to your fingertips.

Notably, it includes a third button, a feature frequently requested by creative professionals working in industrial design, game design, animation, virtual and augmented reality and 2D/3D art.

This button provides additional ways for users to manipulate and speed up the design processs, allowing designers and artists to do most of their work in 3D applications right from the pen, without having to touch their keyboard.

The pen's default settings for the third button controls tumbling and rotation, engaging users with all the small details in a 3D model.

The Wacom Pro Pen 3D retains the same performance features that creative professionals love in the Wacom Pro Pen 2, including 8192 levels of pressure sensitivity and a sensitive pen tip. All settings and functions can be customised to suit the user's preferred style of work and workflow.

Built to work with any Windows or Mac application, Pro Pen 3D provides a natural digital experience and unparalleled control.

The aluminium barrel and slightly thinner grip give it a new, sleek appearance and make it a great tool for any designer or artist working on one of Wacom's professional creative products.

The Waco Pro Pen 3D is priced at $149.00 inc. GST and is available direct from Wacom or from selected retailers.

Contact:
Wacom Australia
Bldg1, 3 Richardson Pl, North Ryde 2113
Tel: (02) 9422 670 **Fax:** (02) 9422 6755
Website: www.buywacom.com.au

SERVICEMAN'S LOG

The stereo recorder that wasn't

Dave Thompson*

A friend popped in the other day to talk about video production. He'd heard I was contemplating starting a YouTube channel and wanted to compare notes as to what software and hardware I'd be using. In video production, as in everything else in life, there are many different ways of achieving the same thing.

On the face of it, all you need is a computer, a camera and a good idea, yet many of the various guides on the web related to starting a YouTube channel imply that I'd need a raft of expensive video equipment and associated gadgetry if I was to have any chance at all of success.

Of course, all the "tools" featured in these guides and videos are affiliate-linked in the video descriptions. Those who click through to purchase what they've just been advised as essential kit end up bankrolling the guide authors' own success by lining their pockets with referral commission cheques.

Nice work if you can get it and this explains why there are hundreds of such guides recommending everything from the best cameras, lenses, lights, filters, microphones and recording gear down to the software we can use to edit our masterpieces.

There's nothing wrong with all this as the internet is as valid a platform for marketing and carrying on business as any other medium. What's difficult for the beginner is sorting through the huge amounts of available information to determine what it is we actually need in order to get a viable channel up and running.

Items Covered This Month

- Dodgy stereo recorder
- A failed Bose SoundDock
- Repairing a LED fluoro batten

*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

~NICE WORK IF YOU CAN GET IT

My friend and I agreed that we'd need a camera capable of taking at least high definition video (HD-720p, though Full HD-1080p would be better) and preferably with decent audio capture.

While most modern smart phones have suitable cameras and would probably do quite nicely, a DSLR or similar purpose-built camera is likely to be better at coping with the different environments and situations my videos will most likely be shot in.

A simple high-quality web-cam with built-in audio capture would be adequate if I was just going to sit in front of the computer and do a piece to camera.

However, I intend to be filming in the workshop, in various locations which will all have different focal lengths and lighting requirements, so a "proper" camera will theoretically cope better than any smartphone version.

Separate audio recording

Another consideration is audio capture. While most half-way-decent cameras also have stereo recording via built-in microphones, some have surprisingly limited audio recording capability, so an external microphone or even a separate recorder must be used.

My friend had such a camera and had bought himself a digital audio recorder online to experiment with. He had brought it with him for me to take a look at because he was having some problems with it.

He'd purchased it online from an eBay link in one of those "how-to" videos I mentioned, and while it worked reasonably well, he suspected it wasn't performing as it should.

On the face of it, the digital voice recorder looked like a hot little gadget. He'd only paid something like US$30 for it but it certainly looked the business. It is palm-sized and boasts dual microphones, a built-in speaker and has various sockets allowing for headphones, an external microphone and USB charging/data transfer cables to be attached. It also doubles as an MP3/audio player.

The LCD is clear and reasonably easy to understand and the device comes with a basic set of bud-style headphones, a clip-on lapel microphone and assorted leads for line-in recording. It even comes with an adaptor to allow for recording telephone conversations.

All of this is packed into a plush, velvet carry bag; not too shabby for the money.

Specifications-wise, it has eight gigabytes of on-board storage, features so-called lossless WAV recording at 192kbits/s, voice-activated recording and selectable high/low quality settings, which also affects how much data can be stored on-board.

There is no facility for adding storage space via removable media, but eight gigs should be more than adequate for the sort of work he wants to do with it, with the bumf promising around 48 hours of recording at high quality and 68 hours at the lower-quality setting.

All in all, not too bad and while inexpensive, if it lives up to those specifications, it should be a useful tool for his online video production.

No stereo spread

The main problem he had was recording in stereo. The built-in mics are by design mounted close together but even with an external stereo mic plugged in, he could not get a proper stereo-sounding spread, with both channels appearing audibly the same when played back.

On looking more closely at the device, the dual microphones are clearly marked L and R on the case and while fixed, there are silver mouldings with the usual rows of holes and slots to indicate where they are.

Similar-looking microphones are seen on much-higher-end devices like the well-known Zoom range, except that those microphones can usually be extended or otherwise manipulated to point where the recordist wants them to capture sound from; usually a crossed-over formation is used to ensure a nice, even stereo capture.

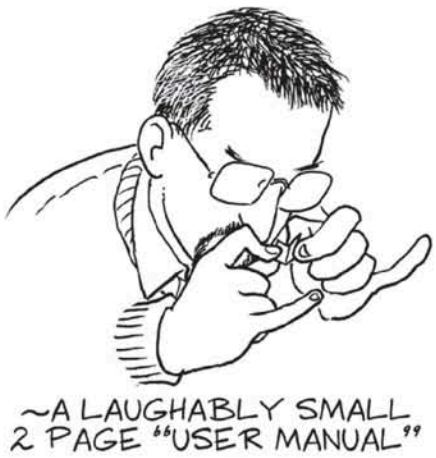
However, the mics on this recorder are fixed facing forward, which means the user must take care to physically position the recorder towards the sound source if they want the best sound capture.

The lapel mic has a 3.5mm stereo plug on the end of a 600mm-long cable, although the mic itself appears to be a mono/single capsule type, while the plugs on the line-in lead are also the same 3.5mm stereo versions. Because of this, I assumed the device is capable of stereo recording.

However, on checking the specifications in the supplied "user manual" (a laughably-small 2-page folded sheet of paper), nothing mentioned stereo recording.

I also found this exact device on AliExpress – at half the cost of what my friend paid for it, though I didn't pass that on to him – and none of the specs there mentioned stereo recording either.

While there is obviously stereo playback – it actually plays MP3 files quite well – my subsequent tests showed it



DIY
SPEAKER
KITS

the loud speaker kit.com

Australia's #1 source for DIY audio kits & components

VISIT OUR ONLINE STORE
www.theloudspeakerkit.com
Ph: (02) 8120 8010

did not record in stereo from any of its input sources.

To prove this definitively, I used the supplied stereo line-in cable to connect the recorder's line input to my computer sound-card's line-out socket; it definitely rings out as a bona-fide stereo lead according to my multimeter.

I set the recorder to HQ, which according to the specs records at a bit rate of 192,000 bits per second (192kbits/s) and played a song on my computer using VLC media player. The source material is definitely stereo and was "ripped" by me from a CD.

After hitting record on the recorder, I played the song and when finished, played it back into my computer after swapping the line-out cable at the recorder to headphones out and at the computer end to line-in.

While the headphone out signal is usually a lot "hotter" than the typical line input can handle, I just made sure the recorder's output volume was very low and this kept everything under control.

I run a piece of software called Audacity – an excellent freeware program I heartily recommend for anyone into manipulating audio data on their computer – and analysed the track as it came out of the recorder.

Both channels were identical, proving the recorder was mixing the two channel sources together into a single, monophonic signal.
Boo! Hiss!

Just to be sure, I did one more experiment, this time using the microphones to record the music as played from my computer through a pair of stereo speakers.

The speakers are only about a metre apart on my desk but the stereo separation is readily apparent and any stereo-capable recorder placed in the centre of the spread should pick up and record the stereo sound quite easily.

After recording the song and playing it back through Audacity, once again the channels were merged, and listening to it played back through the headphones doubly-confirms there is no stereo spread at all in the resulting recording. So it definitely isn't and cannot do stereo recordings. Double boo! Double hiss!

That said, I shouldn't be too harsh; none of the bumf mentions stereo recording and since this was apparently only going to be used for voice work, recording in mono won't be too much of a problem.

The rather mediocre-by-today's-standard 192kbits/s bit rate is also fine for voice capture (192kbits/s is only considered medium quality nowadays).

Added noise as well

However, even if only used for voice, my main concern with any recording device is the quality of the recorded material and especially the signal-to-noise ratio.

In other words, the real test is how well the audio is captured, recorded and reproduced.

A sound track full of hiss, clicks or pops is no good to anyone. While many software programs are available that make a reasonable attempt at removing hiss and other noise from recordings; it's much better to reduce any noise at the source rather than try to electronically remove it after the fact.

The problem with any recorder, no matter the cost or quality, is that noise is produced all the way along the recording chain. The tiny mic capsules add noise; amplification adds noise; any equalisation or normalisation circuitry adds noise and even the headphones or speakers add noise. It's a miracle any recorded sound is discernible at all!

After a few simple recording tests, I found the quality of the captured audio to be quite good and while there is a little background hiss at higher volumes, it is at an acceptable level – at least to my years-of-rock-and-roll-damaged hearing.

However, a bigger problem with digital recorders such as this one is handling noise. If using the built-in microphones, the recorder would ideally be used sitting on a desk or other stable surface.

Even so, anything bumping or touching the platform while recording can result in unwanted noise being transmitted through the chassis of the recorder, which is why many "better" digital recorders at least try to isolate the mics from the rest of the unit.

These mics might be rubber-mounted or have some other method of sonically-isolating them from the recorder so that it can be carried around or otherwise handled without lots of added noise but not so with this recorder!

If held in my hand while recording, any tiny movement of the case against my skin is amplified and is very apparent on playback. If sitting on the bench and the bench bumped, the sound is transmitted directly to the microphones.

Scratching the table's underside far away from the mic results in a clear reproduction of the noise on playback, proving it is transmitting through the plastic case to the capsules.

None of this is very scientific and any audio engineers reading this are probably shaking their heads but all this leads me to conclude there is no microphone isolation used at all.

However, simply using an external mic should resolve this problem. Plugging in an external mic usually disables on-board mics, so my friend could just use the supplied lapel mic clipped to his shirt collar and have the recorder in his pocket.

This is all good in theory but when I plugged in the lapel mic to try this out, I could still hear the handling noise, seemingly at the same levels, and it turns out that the on-board microphones are not disabled when the external mic is plugged in. Triple boo!

Surely it would be easy enough to use a set of contacts in the external mic socket to disable the onboard mics?

Every other recorder I have used, that has provision for an external microphone, has the internal mics disabled whenever an external microphone is plugged in; it just makes sense to have this happen.

Perhaps in this one the socket hadn't been wired correctly or something else was amiss inside the unit. It was time to take a look.

The recorder was held together with six small, self-tapping screws and though I had to break through one of those screw-cover type security stickers, my friend said he was OK with voiding the warranty as he was unlikely to go through the hassle and expense of returning it, regardless of the outcome.

I wasn't too surprised when I discovered the reason why we could only get monophonic recording with the mics; there is only one capsule!

While the shape, design and printing on the exterior of the case implies dual microphones, the sole electret capsule is mounted on the right side only.

To make matters worse, it isn't even mounted pointing forward, but is instead soldered at a 90-degree angle to the sound source if the case is pointed straight ahead.

No wonder the recording isn't that flash, as capsules are designed to be either omni or uni-directional; with no part numbers evident on this capsule there was no way, other than carrying out some complex testing, to accurately determine which type of capsule was used.

I considered it might be a dual capsule (if such a thing even exists?), so I checked for multiple leads coming from the capsule. As I suspected, there were only two leads; one ground and one live lead to the circuit board.

So what about the possibility of rewiring the mic socket so that the internal mic is disabled when an external mic is plugged in?

Unfortunately, that option wasn't possible and the accompanying pictures make it bleedingly obvious why that simple modification just isn't possible.

Inside the cheap recorder you can see the sole electret microphone aimed towards the right speaker grille.

There simply isn't any room inside the case to make any mods at all; not even to re-orient the mic capsule to possibly improve sound pickup. What an absolute con!

Yes, it is a nice looking little package but it just goes to show that appearances can be really deceiving and you cannot take anything for granted. If anything, when you decide to purchase something cheap online from Asia, you probably should be prepared to be disappointed. On the other hand, if a cheap purchase turns out to be a good product, you are a winner.

One can hope that more expensive recorders would not rely on deception, but either way I would read the specifications very carefully and not take cheaper goods at face value before buying anything.

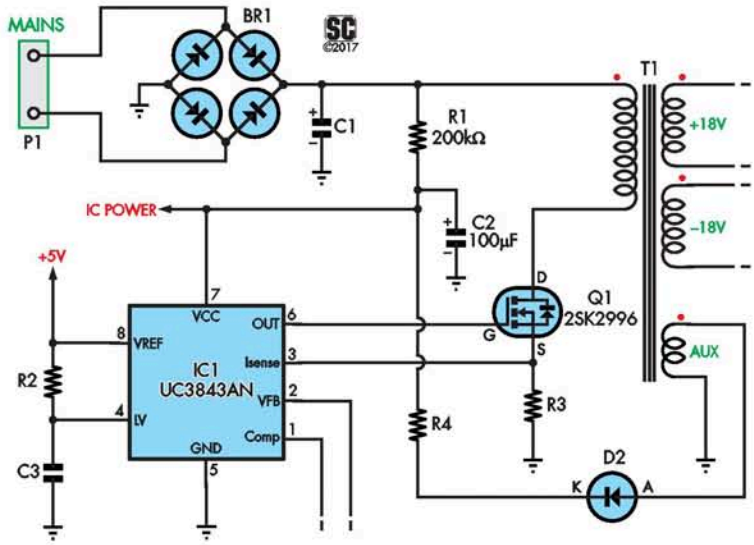
I called my friend and told him and while he was disappointed and a little annoyed at being duped, he was philosophical and agreed that he didn't pay a lot for it and it would suffice for his needs, at least until he started making money (if any) from his channel, after which he could invest in some better gear.

To be fair, the recorder does an OK job of recording him talking and the noise is manageable as long as the device sits somewhere where it isn't likely to be bumped or handled whilst recording. He posted a test video privately and the results were actually better than I thought they'd be.

Throughout all of this, I started thinking that the better way to go for myself would be to use a camera with a good-quality external mic.

However, these mics can be costly, which led me to start thinking about making my own, possibly using one of the 34mm microphone capsules I've had my eye on purchasing online for a while now.

These capsules are used in high-quality broadcast microphones, and with the right pre-amp and phantom power supply circuit, I could make a mic that would be comparable with the commercially-available models.



Partial circuit diagram of the power supply for the Bose SoundDock.

It would certainly be a good video project, however, I'd better do some more due diligence before I go buying anything...

Bose SoundDock repair

J. W., of Hillarys, WA managed to keep his daughter happy by repairing the power supply for her (no doubt pricey) Bose SoundDock after it failed. Here's the story in his own words...

My daughter recently tried to play some music on her Bose Series 1 SoundDock but could not get it to work. I tried it with another iPod but still no music.

I noticed that the iPod was not charging either, so I checked the separate power supply (±18V). Nothing was coming out of it.

I cracked open the power supply case and removed the board, a typical switchmode power supply running straight off the mains. There was no circuit available on the 'net so, before I began checking the board, I plugged the unit into my mains isolation transformer. It always pays to be safe.

The main storage capacitor (C1) was charged to approximately 340V, so that proved the mains input side of the circuit was working OK. I checked the gate of Q1 for switching pulses but found none.

A common problem in switchmode power supplies is electrolytics which have gone low in value, so I checked C2 but found it too to be OK.

I noticed there was a UC3843 IC on the board and discovered from the datasheet that it was a current-mode switchmode controller chip. The data sheet showed that the DC supply went into pin 7 of the IC and was filtered by C2.

A +5V reference should be coming out of pin 8, when the DC supply (across C2) to the IC (pin 7) was above 8.5V. When the under voltage lockout (UVLO) circuit detected a voltage lower than that, the 5V reference was disabled.

I checked both voltages, only to find no 5V and the supply at pin 7 was only 8.3V. After reading the datasheet more thoroughly, it became clear that during normal operation, power for the IC came from the auxiliary winding on the transformer, through D2 and R4. R1 provided a small bootstrap current (about 1mA) which was supposed to get the circuit running initially.

This is because Q1 must be switched on and off for an AC current to flow through the transformer's primary winding and without this, there is no voltage at the secondary and hence no current flow through D2. So the current from R1 has to be sufficient to start Q1 switching, at which point D2 takes over and powers the IC with greater efficiency.

I could not get a decent signal on my CRO to see what was happening at start-up so decided to cut a track and put a switch in the power line to the IC. This enabled me to toggle power to

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

Reparing a modern LED "fluoro" batten

G. C., of Tawa, in New Zealand loved the increased light output from an array of new LED battens but one of them failed straight away. Fortunately, the repair was easy. He writes...

I recently purchased 14 40W 230VAC 1.2m long LED light fittings to replace in like-for-like fashion, a similar number of old twin 40W fluorescent light fittings.

These LED fittings were of the Philips brand and were easily installed in place of the original fluoro light fittings, after drilling a new cable hole in the fitting base to suit the original cable installation.

Although I do not have any actual light output readings, the new (38W measured consumption) LED fittings were clearly much brighter than the old 80W fluoro fittings, even though they were less than half the wattage.

In fact, the LED's light output without the diffuser fitted was too bright to look at. But we could live with that brightness because of the general increase in lighting levels with the diffuser fitted.

Anyway, after turning on the second group of seven newly installed LED lights for the very second time, there was an ominous "phut" noise from one light fitting and the unit was now dark.

Well, that seemed to prove the old adage that one could expect an 5% failure rate of new electronic equipment; after installing 14 fittings, that would be about right.

But I actually expected better of Philips-branded equipment even though the light fitting was clearly made in China. So, after opening up the LED fitting again to gain access to the supply input terminals, the 230VAC supply was found to be present so the fault had to be with the light fitting.

These light fittings have a layout of one long row of 96 white SMD LEDs, nearly 1m long. Electrically, two series strings of 48 LEDs were in parallel and were powered from a Philips-branded 230VAC to 160V DC switch-mode power supply unit mounted inside the LED light fitting.

With no voltage reading on the power supply output, it was clear that the power supply unit had failed in the first instance.

But had a fault with the LEDs caused the power supply to fail? Other than borrowing a power supply from another LED fitting, I had no easy means of providing a 160V DC power supply to test the LEDs with, so that idea was put aside for the meantime.

So what to do? Should I claim a replacement power supply (probably not available) or claim a complete new light fitting, under warranty?

Or should I take a look at the power supply unit with a view to fixing it, as I was naturally curious to know what the failure was for future reference?

In any event, it was easy to pry the metal lid off the power supply and ease the clipped-in PCB out of its case and examine the electronics.

My thinking was now that if the fault was not obvious, I could always put the unit back together again and claim the warranty replacement (as there were not going to be any access screws with broken seals to indicate the unit had been tampered with!).

But with the power supply unit out of its case, the cause of the initial failure was immediately obvious – one 10mm long PCB "fuse track" in the incoming 230VAC Active mains supply line was blown and clearly violently blown at that.

That would account for the "phut" heard at the time of the failure. As the unit was rated at 200mA max, I soldered a slim strand of a flexible conductor wire that I deemed to be about the same size as the printed circuit track across the blown track; not an elegant fix but perhaps a practical one, to allow for further testing.

But what had made the fuse track blow? A look at the 230VAC input circuitry revealed some suppression equipment and a 4-diode full-wave diode bridge.

It was easy to see these plastic diodes had the markings of the venerable 1N4007 1000V 1A type and a quick check with a DMM showed that one of the diodes was short-circuited.

With a bit of luck, this should be an easy fix, as I had my own stock of 1N4007 diodes. The old diode was de-soldered, a replacement diode fitted and then I was ready for the smoke test.

This was an anti-climax as the power supply now gave out the expected open-circuit voltage of about 200V DC, with no spectacular fuse failure display.

In due course, the power supply unit was re-fitted into the light fitting base and the LED tray re-installed on top. Then when the covers were replaced, the installation was again powered and it all worked, as expected. So, that appeared to be it; a faulty 1N4007 diode had caused the problem.

So should I have claimed a replacement power supply unit under warranty? Some would say I should have. But at least I had the satisfaction of knowing what the fault was and that I had saved an otherwise good piece of modern lighting equipment from the rubbish tip.

Probably all the supplier would have done was give me a replacement light fitting and throw the faulty light fitting away.

the IC without turning the mains supply on and off.

I could now see what was happening when the IC was first supplied with power. There was a 20ms time frame where the +5V reference appeared and pulses came from output pin 6 to switch the primary of the transformer via Q1.

The auxiliary feedback winding then showed pulses which should have been rectified to provide charging current to C2 and so allow the IC to continue to run.

Upon testing D2, I found it to be open-circuit. So the IC was doing its job and getting the switching started but then could not continue with just the bootstrap current, as it requires 17mA for continued operation.

I replaced D2 and was rewarded with ±18V at the output connector; a great end to a few hours of circuit fault finding as my daughter has music again. SC

12V Automotive Variable Speed Fan Controller

This 12V speed controller could be used in any vehicle with an intercooler or one with inadequate fans – or indeed in any application where there is a need to control the speed of a low voltage DC fan or fans in response to changes in temperature. Simple to wire up, it can control up to 120W of fans.

We designed this Speed Controller to run the intercooler fan on a performance vehicle. We looked for pre-built units on ebay and AliExpress but nothing really suited the application.

Simple 12V on/off thermostats suitable for automotive applications are available but surprisingly expensive given their simplicity.

We found very few which could actually vary the fan speed and these were both expensive and highly complex, with dozens of wires.

Why do variable speed controllers need to be so complicated? Assuming the fan and battery are earthed to the vehicle, all you really need is one wire for power and one for connection to the fan, a temperature sensor and maybe a few adjustments to allow you to set the temperature threshold and so on.

Of course, some fans may not be earthed – and there are doubtless many non-automotive applications which will require extra connections – but overall, it's pretty simple!

But we couldn't find a suitable controller, so we decided to build one.

by Nicholas Vinen

We deliberately kept the design as simple and low-cost as possible, while satisfying a long list of requirements:

- It had to be easy to wire up, because chasing wires and messing with a packed fuse box in a motor vehicle can be a nightmare.
- It must not flatten the vehicle battery if left unattended for long periods.
- It needed to be able to run a powerful fan, able to keep a large engine cool.
- It needed to be easy to set up and tweak. And so on.

Our design fits all the above criteria – and can do the job anywhere you need to run a 12V DC fan to control temperature

How it works

The general concept is shown in the simplified circuit of Fig.1.

In essence, it is a PWM (pulse-width modulation) controller with inputs for battery voltage and temperature. A comparator monitors the battery voltage against a 4V reference. This stops the fan from

running if the battery voltage is below a preset value.

Trimpot VR1 allows the switch-on threshold voltage to be set between 8.4V and 16.8V. For automotive applications, you would normally set it to switch on for voltages above 13.5V, so that the controller will switch on when the alternator is running and switch off once the engine (and thus alternator) stops.

A comparator feedback resistor adds around 0.5V of hysteresis so that once the supply voltage has risen high enough for the fan controller to be activated, the voltage must drop by a further 0.5V below this threshold before it will switch off.

This prevents the fan from "chattering", or being rapidly switched on and off. The PWM controller includes a two-second switch-on delay which also helps prevent this.

Temperature is monitored by an NTC thermistor which is connected in series with trimpot VR2, with the two components connected between the 5V supply rail and GND (0V). This provides a voltage which varies with temperature, rising as the thermistor gets hotter. This is the control voltage input for the PWM controller so that the fan duty cycle, and thus speed, rises as the temperature increases.

Features & specifications

- Proportional fan control (PWM, 1% increments)
- Runs from 12V DC
- Compact, light and easy to build
- Designed to survive in the harsh automotive electrical environment
- Fan power up to 120W (maximum current 10A)
- Fan soft start and gentle spin-down
- Under-voltage lockout (UVLO) with hysteresis
- Adjustable UVLO threshold (8.4-16.8V)
- Ultra-low quiescent current when shut down (<20µA)
- Fan switch-on temperature adjustable between -7.5°C and +100°C
- Maximum fan speed temperature also adjustable
- Sealed lug-mount thermistor can be used for temperature sensing
- Minimum and maximum fan duty cycle can be changed (default: 25%/100%)
- PWM frequency can be set from 50Hz - 1kHz (default: 1kHz)
- Fan speed compensation applied for variations in supply voltage

The circuit

Now have a look at the full circuit of Fig.2. Both the comparator and the PWM controller functions are provided by a PIC12F675 microcontroller. Compared to a discrete design the micro gives a lower component count and lower quiescent current; important when the fan and motor is off.

The PIC does three main jobs: it monitors the battery voltage, reads the thermistor temperature and drives the gate of Mosfet Q1 to control the fan speed in response to these readings.

Soft start and power saving

The micro provides a soft-start feature where the PWM duty cycle will only change by 1% every 100ms.

So if the unit is switched on while the sensor is hot, the fan will ramp up to maximum speed over about ten seconds. This limits the current drawn from the supply and should also reduce its tendency to "hunt" for a particular speed (ie, varying up and down periodically).

One particular difference between the full circuit of Fig.2 and the simplified version of Fig.1 is that the voltage divider which allows IC1 to monitor the battery voltage is not connected directly to the 12V supply.

Instead, current flows from the 12V input, through fuse F1 and the 470Ω series resistor and then to transistor Q2's emitter. Q2 must be switched on in order for current to flow to the divider, thus allowing IC1 to measure the battery voltage.

This is a power-saving measure; Q2 is held on while the fan is operating but if the low-voltage cut-out is engaged and the fan is switched off, Q2 is also switched off, so no current flows through this divider. It is only energised for around 1ms every two seconds, when the unit re-checks the supply voltage to see if it is high enough to continue operation.

Thus the 0.3mA which would flow through this divider is reduced to an average of just 0.15µA. That's important when the quiescent current of the rest of the circuit is below 20µA. Otherwise, the divider current would swamp it, increasing the quiescent current by a factor of 15 times.

We've done something similar with the other two dividers formed by the NTC thermistor and trimpot VR2, as well as trimpot VR3.

The upper ends of both dividers are shown connected to +5V in Fig.1 but as you can see from Fig.2, they are driven from output pin GP0 of IC1 instead.

This pin is brought high, to +5V during normal operation but is brought low to 0V when the supply voltage is low, reducing the quiescent current by a further 1mA or so. And because GP0 drives the base of NPN transistor Q3 which in turn drives Q2, bringing GP0 high enables all three dividers simultaneously.

IC1 checks the battery voltage every two seconds if it's inactive (due to low battery voltage) or every 100ms if it's active. The 1nF capacitor from pin 6 to ground provides a small amount of filtering for this battery voltage, rejecting noise and also reducing the source impedance for IC1's internal analog-to-digital converter (ADC), which can affect the accuracy of its readings.

We stated earlier that the range of low-battery cut-out voltages is from 8.4V to 16.8V.

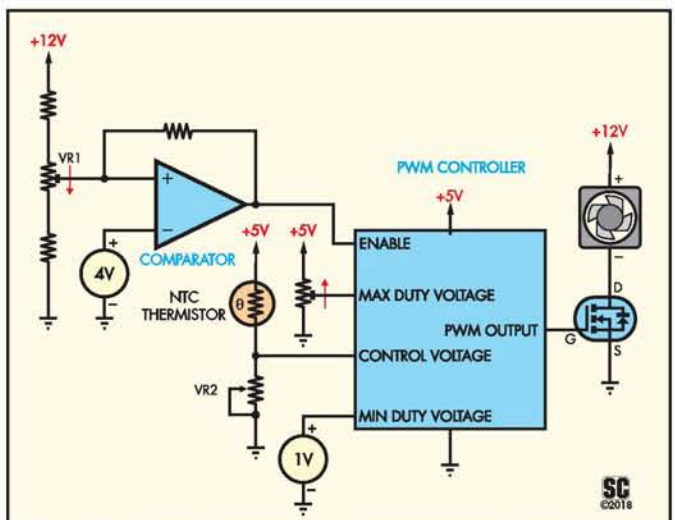


Fig.1: the circuit concept is a comparator to monitor the battery voltage and a thermistor to monitor temperature.

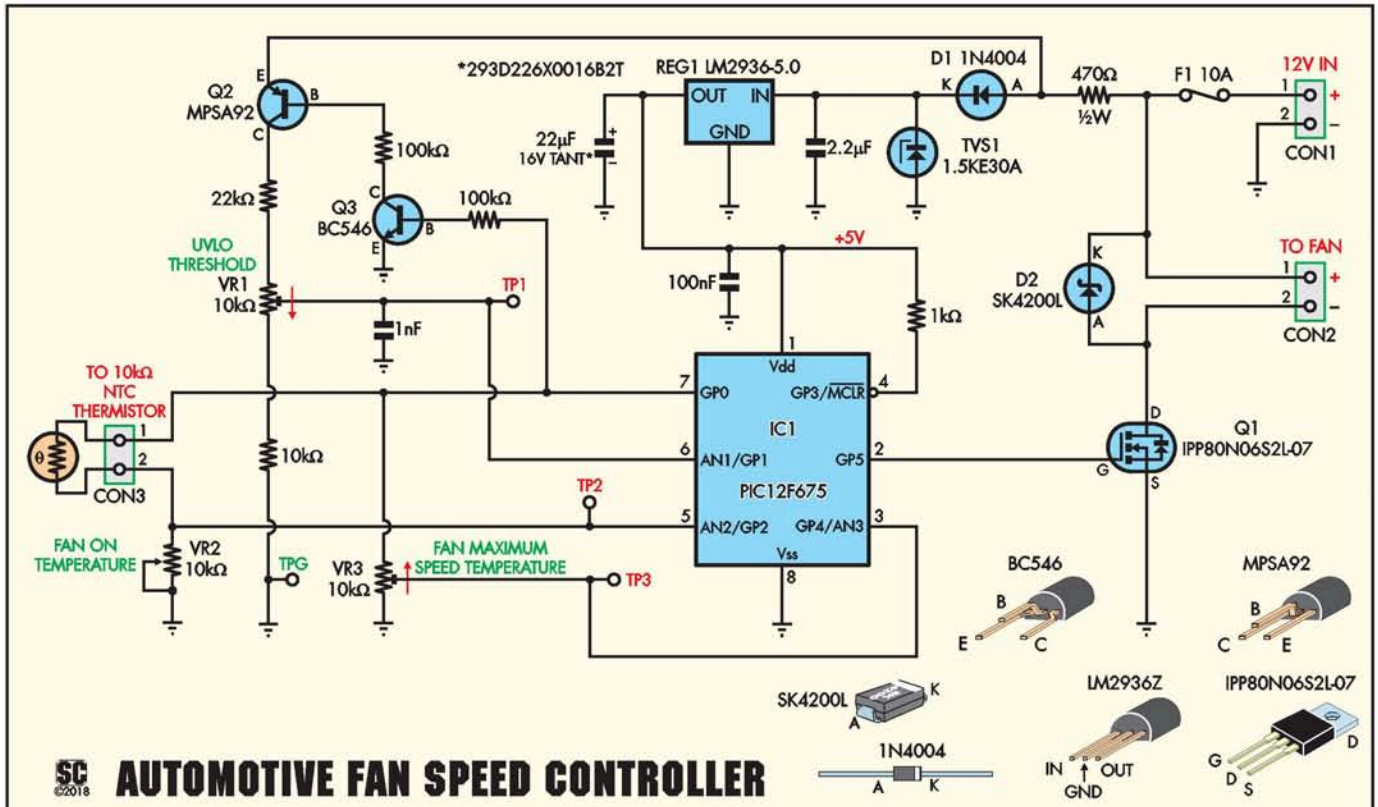


Fig2: micro IC1 monitors the battery voltage, the air temperature and sends a PWM signal to drive the mosfet, which in turn controls the fan speed.

You can verify this by calculating the division ratio of the UVLO divider with trimpot VR1 at both extremes and then multiplying this by the pin 6 threshold of 4V, set in the software.

Actually, the threshold is 4.0V for the unit to switch on and 3.8V for it to switch off, ie, there is a 0.2V hysteresis. This translates into a supply voltage hysteresis of around 0.4-0.8V, depending on the setting of VR1 (because of the voltage divider feeding pin 6). This reduces the chance of the unit constantly toggling on and off because of the voltage drop caused by the fan switching on.

Temperature sensing

When the voltage at pin 6 is high enough for the unit to become active, it measures the voltages at input AN2 (pin 5) and input AN3 (pin 3) every 100ms.

The voltage at AN2 is determined by the resistance of the NTC thermistor (which is connected via CON3) and the setting of trimpot VR2. The thermistor has a nominal resistance of 10kΩ at 25°C while VR2 can be varied between about 0Ω and 10kΩ.

As trimpot VR2 is turned clockwise, its resistance drops and therefore the NTC thermistor resistance must drop further to achieve the same voltage at pin 5. Since by definition, an NTC thermistor's resistance drops as its temperature rises, it follows that turning VR2 clockwise increases the required temperature to achieve a certain voltage at pin 5.

Analog input AN3 is simply connected to the wiper of VR3, which is connected between GP0 and GND, thus varying the voltage applied to AN3, providing a convenient way to set the temperature required to achieve maximum fan speed.

Since IC1's ADC is configured to use the 5V rail as its reference, and the dividers feeding both AN2 and AN3 are effectively between 5V and 0V, the readings it takes at both AN2 and AN3 are ratiometric. Thus, variations in the 5V supply voltage will not change either of these readings, assuming that output GP0 is close to 5V when high; it should be, given the relatively light loading.

The software compares the reading at AN2 to a fixed 1V (nominal) reference and the reading from AN3 and uses these values to compute the required duty cycle for PWM output GP5. If AN2 is below 1V, the target duty cycle is zero. If it's equal to or above the reading for AN3, it will be close to 100% and anywhere in between will result in a duty cycle value between the programmed minimum and maximum values (25% and 100% by default).

So as described above, VR1, VR2 and VR3 allow easy adjustment of the three main settings: the switch-on supply voltage, fan switch-on temperature and maximum fan speed temperatures respectively.

There are actually three additional settings but these are not set via trimpots (at least, not directly). These are the PWM frequency, the minimum fan duty cycle and the maximum fan duty cycle. They default to 1kHz, 25% and 100% respectively.

There is a procedure to go through if you want to change any of these, and the altered setting is stored in EEPROM inside IC1. See below for details.

Fan drive

The GP5 output (pin 2) drives the gate of Mosfet Q1 directly. Q1 is a low on-resistance, logic-level type with a low gate capacitance. As such, it is reasonably efficient when driven in this manner (without a dedicated Mosfet driver

or even series resistor), although we have purposefully kept the frequency low (50-1000Hz) in order to keep switching losses under control.

Basically, there are two types of losses in the fan drive system, both of which contribute to heating in Q1 and if the total is excessive, Q1 could be damaged. These are more-or-less fixed losses due to Q1's on-resistance and switching losses due primarily to the fact that Q1 is in partial conduction (ie, higher than normal resistance) while it is in the process of switching on and off.

The faster Q1 switches, the lower the switching losses but this fast switching requires a high current to be sourced/sunk to the gate terminal, to rapidly charge and discharge it. Hence, with a relatively low drive strength available from the general purpose output pin on the micro, we can expect higher switching losses.

Switching losses are proportional to the drive frequency since the more gate transitions there are per second, the more time it spends in partial conduction. Hence, keeping the frequency relatively low helps. The only real disadvantage is that, since 1kHz is an audible frequency, you may hear some whine from the fan motor when the duty cycle is between 0% and 100%.

In our test vehicle, the fan noise is drowned out by the V8 engine. In fact, it's hard to tell from behind the wheel, whether the fan is running at all (this is not true of the factory-fitted radiator fans!).

It may be more problematic if you're controlling a fan to cool a desktop PC or some other domestic situation, but we have provided a way to minimise this, as we shall explain later.

By the way, Q1 is an automotive-rated Mosfet and typical dissipation can be expected to be under 1W for loads up to 10A, so no extra heatsinking is required.

4A schottky diode D2 is connected across the fan motor output terminal, to absorb back-EMF when Q1 switches off and inject it back into the 12V supply. Q1 is avalanche-rated and should survive without D2 but we decided to add it as a "belts 'n' braces" measure; you don't have to install it if you are sure it's unnecessary but it certainly doesn't hurt.

Battery voltage compensation

Our description of how the duty cycle is calculated above omitted one detail. While fan speed is related to the duty cycle applied to Q1, it will also vary depending on the supply voltage. In order to provide a consistent fan speed based on temperature, we apply some supply voltage compensation.

This means is that when you set the control voltage for 100% fan duty cycle, we consider this to be full speed at the minimum supply voltage as set by VR1. As the supply voltage rises above this minimum, the fan duty cycle is reduced proportionally.

So for example, if the switch-on voltage is set to 13V but the actual supply voltage is 14.4V when the control voltage reaches the maximum setting (as determined by VR3), the actual duty cycle will be reduced to 90% (100% x 13V ÷ 14.4V). This means the fan speed should not vary (much) as the supply voltage varies.

However, that does not mean the unit will never exceed a duty cycle of 90% when the supply is at 14.4V. It will still increase the duty cycle if the control voltage (ie, temperature) increases further beyond the "maximum" setting. It will continue increasing duty cycle linearly until Q1 is fully switched on (ie, 100% duty cycle). You can think of this as a bit of a "turbo" mode for your fan when the supply voltage is high enough.

Power supply

Because this unit can be used in automotive (or even marine) applications, where you can expect all sorts of spikes and dips and other nasties on the supply rail, we have included protection measures to prevent the unit from being damaged.

Power coming into the unit first passes through 10A blade fuse F1. This is mainly to protect against a shorted fan motor. In a motor vehicle, the unit should always be connected with an external fuse between the unit and the battery (either in the fuse box, or inline with the wiring) but it's a good idea to have an internal fuse, just in case.

The fan connects directly between the fused 12V rail and the drain of Mosfet Q1. Q1 is designed for automotive use and has an avalanche rating of 450mJ, which is relatively high. This, in combination with the inductance of the fan motor, should allow it to handle the typical brief (but high voltage) spikes which can occur in an automotive DC supply.

But the rest of the circuit has separate protection, with a series 470Ω 0.5W resistor feeding reverse-polarity protection diode D1 and transient voltage suppressor TVS1, which is bypassed by a 2.2µF ceramic capacitor. These feed REG1, which is an automotive-rated ultra-low quiescent current linear regulator.

The 470Ω resistor and 2.2µF capacitor form an RC low-pass filter to reduce the severity of the spikes, while TVS1 clamps the larger ones to a maximum of about 40V, which is the upper limit to the operating voltage rating of REG1. The 470Ω resistor also acts to limit the maximum current that TVS1 must clamp.

REG1 is a low-dropout linear regulator and these tend to have stability issues depending on the output filter capacitor used. That's because they have an internal feedback loop with significantly more phase shift than a traditional linear regulator. We have carefully chosen the output filter capacitor to have an ESR in the required range for stability.

We would have preferred to use a ceramic capacitor, as these tend to be more reliable but they almost universally have too low an ESR to suit the LM2936 regulator. We could have added a series resistor but that would be another component on an already packed board.

The Vishay 293D-series tantalum capacitor has an operating temperature range of -55°C to +125°C, with suitable voltage derating. In fact, we've provided a sufficient voltage rating for the capacitor to be OK up to temperatures of +150°C and Vishay's reliability calculator suggests this part in our application should have a mean time between failures (MTBF) of 17 million hours at a constant 125°C. So it should be OK for, oh, just on 2000 years!

The only additional components in the circuit are the 100nF supply bypass capacitor for IC1 and the 1kΩ pull-up resistor at its $\overline{\text{MCLR}}$ input, to prevent spurious resets.

Construction

The Fan Speed Controller is built on a very small double-sided PCB, just 49.5 x 30.5mm and coded 05111171. Almost all the components are through-hole types and are fitted to the top side; there are just two SMDs, both on the bottom side and both easy to solder.

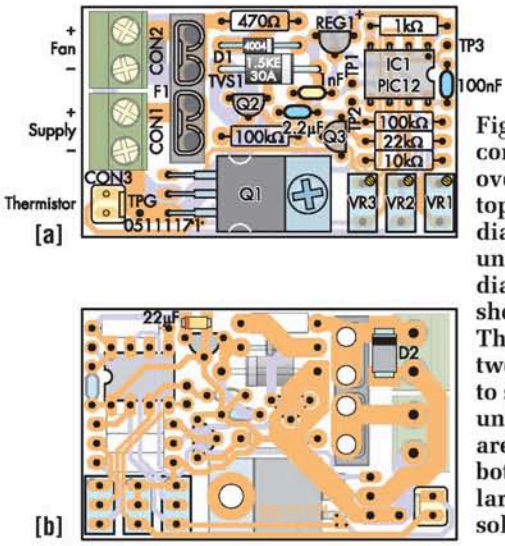
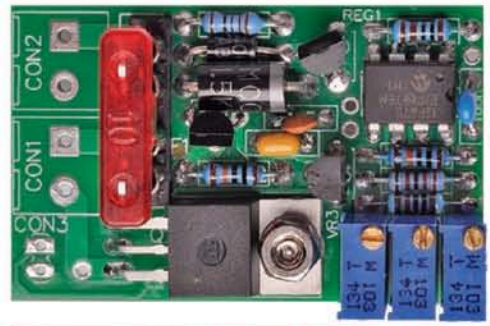
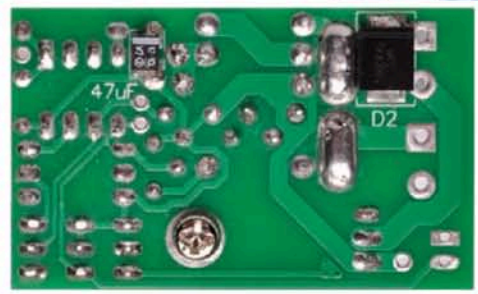


Fig.3: the PCB component overlays for the top side (top diagram, [a]) and underside (bottom diagram [b]), both shown life size. There are only two components to solder on the underside – both are SMDs but both are quite large and easy to solder.





For clarity, we've shown the topside and underside views of the PCB a little larger than life size. Note the polarity of the 22µF tantalum capacitor and the schottky diode (D2) on the underside pic. There are some minor differences between this prototype and the patterns at left.

One SMD is the 22µF tantalum capacitor in a B-size case (3.2 x 2.6mm) and this is soldered in place under the mounting location for REG1. It's a polarised component and will have a stripe to indicate the positive side. This must go towards IC1; see bottom side overlay diagram Fig.3(b). This also shows the location for schottky diode D2, with its cathode (striped end) towards the top (near) edge of the PCB.

The main thing to watch for with these components is to make sure that the solder forms a good fillet between the rectangular lead on the end of the component and the pad on the PCB. If you spread a little flux paste on the PCB pads before soldering, it will help the solder flow down and make good contact with the PCB.

With those in place, flip the board over and start fitting the through-hole components, using top side overlay diagram Fig.3(a) as a guide. Start with the resistors, checking the resistance of each with a DMM before soldering, followed by diode D1, with its cathode stripe orientated as shown. TVS1 is also polarised and this can be fitted now.

IC1 is next but make sure it is programmed before soldering it in place. It's difficult to re-program once on the board and we strongly recommend that you don't use a socket since the IC could vibrate loose or corrosion could form over time, causing intermittent contact and failure. Double-check that its pin 1 dot is towards the corner of the board before soldering the pins.

The next job is to mount Q1 on the board by bending its pins and then attaching its tab using a short M3 machine screw, shakeproof washer and nut. Once it's firmly secured, solder and trim the three leads. You can now fit the three non-polarised ceramic capacitors in the locations shown.

Now crank out the leads of transistors Q2 and Q3, and regulator REG1 and solder them as shown in Fig.3(a). Don't get the parts mixed up since they look almost identical and are only distinguishable by their labels. You can then solder the three identical trimpots, VR1-VR3, with their mounting screws located as shown.

That just leaves fuse holder F1 and the three connectors. If you are wiring in the unit with an inline fuse (strongly recommended for automotive applications), you could replace F1 with a wire link. However, we opted to keep the onboard fuseholder and we fitted a 10A fuse, with a 7.5A inline fuse. The idea behind this is that the inline fuse is easier to replace and so should blow first but the onboard 10A fuse has been kept as a last-ditch protection measure.

Assuming you are fitting F1, you will either have two separate blade fuse clips or a single assembly with both clips fitted to a plastic base. Either way, you will need to insert the clips as shown and push them down fully onto the PCB before soldering.

But if you are using the individual clips, you will have to be careful because it requires quite a lot of heat to get good solder adhesion and the solder can unfortunately run down through the middle of the clip, preventing a fuse from being inserted. We certainly don't recommend you solder the clips with a fuse inserted since this can result in the fuse being soldered to the clips!

So it's a balancing act; you need to use enough solder and heat it sufficiently for it to adhere to the clips but not so much that it runs through. If you do get solder inside the fuse clips, you will need to use a solder sucker and probably also some flux paste and solder wick to remove the excess.

Note that we didn't fit any of the connectors to our prototype because we were concerned that the wires could vibrate loose and contacts could corrode, so we decided to solder the wires directly to the PCB.

If you do fit the connectors, make sure the wire entry holes of the terminal blocks face to the outside of the PCB (ie, to the left as shown in Fig.3). There's no need to dovetail the terminal blocks as they are spaced apart slightly.

If you aren't fitting the connectors, we strongly recommend that you make sure the wires will fit through the holes before going any further. Since the holes are sized to suit connectors and thus are too small to admit high-current wires, you will probably be better off soldering PCB stakes to the board and then solder the wires to the stakes later.

You could drill out the holes for CON1 and CON2 to accept wires but then we suggest you solder them to both sides of the board, so you can take advantage of the parallel copper tracks top and bottom.

Fitting it in its case

We chose an IP65 flanged polycarbonate case for this automotive application because the unit needs to be waterproof

Testing and set-up

Fig.4 shows an easy way to test and set up the Fan Speed Controller. The LED and series resistor take the place of the fan and show you when it will switch on and how fast it will be running (ie, how bright the LED is). The 1kΩ potentiometer allows you to vary the supply voltage to the board and the 10kΩ potentiometer simulates the NTC thermistor and allows you to simulate changes in temperature.

If you have an adjustable DC bench supply, you can do without the 1kΩ potentiometer and simply connect the supply up directly to CON1.

Insert fuse F1, wind the 1kΩ resistor fully anti-clockwise, switch on the supply and advance the 1kΩ pot to about half-way. Check that you have at least 7V across CON1. If you have much less than that, there could be a short circuit on the board, so switch off and check it carefully.

Now measure the voltage across the 470Ω resistor next to D1 on the board. The quiescent current in this condition should be around 18μA, giving an expected reading of 8.5mV. If you get a reading above 15mV or below 5mV then something is wrong so check your work. Depending on your meter, you may see the reading jump up every two seconds; this is IC1 waking up to check the supply voltage.

If you want to alter the PWM frequency or fan minimum/maximum duty cycle, now is the best time to do it. See the panel titled "Advanced set-up" for instructions.

The first main setting to make is the low supply cut-out voltage. Set the 10kΩ off-board pot to about halfway, then wind VR1 and VR3 fully clockwise and VR2 fully anti-clockwise. Adjust the 1kΩ potentiometer (or your DC supply) to the desired switch-on voltage. Adjust VR1 clockwise until the test LED switches on.

You can now test it by reducing the supply voltage until the LED switches off. If you measure the voltage across CON1, it should be around half a volt lower than the switch-on threshold that you just set.

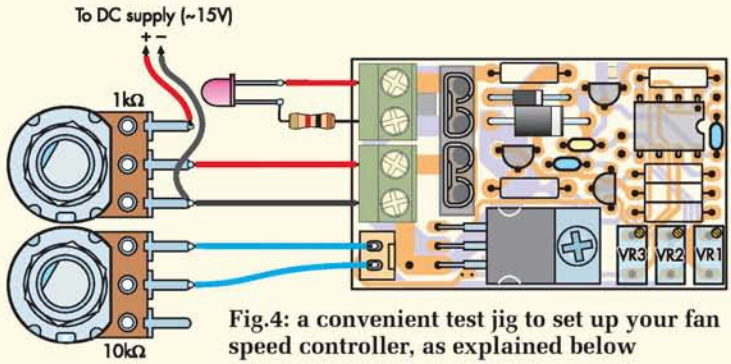


Fig.4: a convenient test jig to set up your fan speed controller, as explained below

Next, we set the switch-on and maximum speed temperatures.

First, refer to the table at right and write down the thermistor resistance at the desired minimum and maximum temperatures. For temperatures between those shown, you can simply estimate the value (it's all pretty approximate anyway).

For example, for 38°C, we know the resistance will be somewhere between 6.5kΩ and 5.3kΩ and probably closer to the latter, so we could take a guess at 5.8kΩ, which turns out to be spot on.

Now adjust your off-board 10kΩ potentiometer while measuring the resistance between the two pins that are wired to the board, until you reach your computed switch-on threshold value. Then rotate VR2 clockwise until the test LED lights.

Now, re-adjust the 10kΩ potentiometer to get a resistance reading that corresponds to your maximum speed temperature, and rotate VR3 anti-clockwise until the test LED starts to dim, then slowly rotate VR3 clockwise again until it is back at maximum brightness.

That completes the set-up; you can now connect the NTC thermistor to CON3 and apply a heat source to it and verify that the LED behaves as expected.

Temperature (°C)	Resistance (Ω)
-10	55.3k
-5	42.3k
0	32.7k
5	25.4k
10	19.9k
15	15.7k
20	12.5k
25	10.0k
30	8.1k
35	6.5k
40	5.3k
45	4.4k
50	3.6k
55	3.0k
60	2.5k
65	2.1k
70	1.8k
75	1.5k
80	1.3k
85	1.1k
90	900
95	800
100	700

(to handle rain, car washes, etc) and also able to handle temperatures up to 100°C (eg, engine coolant) without damage. At 64 x 58 x 35mm (not including flanges), this case is nice and compact, making it easy to mount in the engine bay.

While it's available in a beige and dark grey, unfortunately, the dark grey version is only rated for temperatures up to 85°C and the beige version would look out of place in an engine bay.

So we painted the outside of the beige case with a layer of etch primer and then several coats of matte black engine spray paint (intended for painting rocker covers and such).

We were careful to avoid getting paint into the channel where the waterproof gasket is fitted as this may affect its sealing properties.

Even though the case is waterproof, due to the harsh environment of an engine bay it would also be a good idea to spray both sides of the PCB (avoid the top of the preset pots) with a conformal coating, such as HK Wentworth's Electrolube HPA. This makes the PCB and components virtually impervious to liquids.

Do this after verifying that the PCB assembly is working properly.

We glued the PCB into the bottom of the case using neutral cure silicone sealant. Don't use acid cure silicone; it can corrode metal parts. It was then just a matter of drilling holes into the case for the wiring, feeding it through, soldering it to the board and then using silicone to seal the areas where the wires enter the case.

We chose to solder the wires to the board, rather than using terminal blocks and headers, because we were concerned that vibration could work the wires loose over time. Be careful if you do this

Jaycar's HB1022 IP65 case is ideal for this project because it has both a sealing gasket and a mounting flange. And it's just big enough to house the PCB!

Parts List – 12V Fan Speed Controller

1 double-sided PCB, coded 05111171, 49.5 x 30.5mm
1 10A ATO/ATC blade fuse with matching blade fuse clips (F1)
1 M3 x 6mm machine screw, shakeproof washer and nut
2 mini 2-way terminal blocks (CON1,CON2) [optional]
1 2-way polarised pin header (CON3) [optional]
1 NTC thermistor [to suit application]

Semiconductors
1 PIC12F675-E/P microcontroller programmed with 0511117A.HEX (IC1)
1 LM2936-5.0 5V 50mA ultra low quiescent current regulator (REG1)
1 IPP80N06S2L-07 N-channel automotive Mosfet in TO-92 package (Q1)
1 MPSA92 200V 500mA PNP transistor (Q2)
1 BC546 100mA NPN transistor (Q3)
1 1.5KE30A 30V 1500W unidirectional TVS (TVS1)
1 1N4004 1A diode (D1)
1 SK4200L 4A 200V SMD schottky diode (D2)

Capacitors
1 Vishay 293D226X0016B2T 22µF 16V SMD tantalum capacitor, Case B
1 2.2µF 50V multi-layer ceramic
1 100nF 50V multi-layer ceramic
1 1nF 50V multi-layer ceramic

Resistors (all 0.25W 1% metal film unless otherwise stated)
2 100kΩ 1 22kΩ 1 10kΩ 1 1kΩ
1 470Ω 1/2W metal film
3 10kΩ 25-turn vertical trimpots (VR1-VR3)

Additional parts for radiator fan control
1 radiator fan drawing up to 7.5A @ 14.7V (eg, SPAL VA09-AP8/C-27S)
1 radiator fan mounting kit
1 64 x 58 x 35mm IP65 polycarbonate enclosure with mounting flange (Jaycar HB6211)
1 SAE plug to battery terminal 7.5A fused lead [Jaycar PP2012]
1 SAE inline socket with 1.8m 16AWG automotive twin lead [Digi-Key Cat 839-1349-ND]
2 M6 brass nuts (or size to suit battery terminals)
2 M6 beryllium copper crinkle washers (or size to suit battery terminals) [element14 Cat 2770730]
1 2-pin Nylon Molex plug to suit radiator fan [Jaycar PP2021]
1 1m length figure-8 10A automotive rated cable (for fan wiring)
1 10kΩ 1% lug-style NTC thermistor [eg, Altronics R4112]
1 1m length figure-8 light-duty automotive rated cable (for thermistor wiring)
1 2-way waterproof plug and socket set (optional, for thermistor wiring; [eg, Jaycar PP2110])
1 adhesive thermal pad or a small tube of thermal paste
heatshrink tubing
petroleum jelly
neutral-cure silicone sealant
a few small pieces of high-density foam
a selection of large and small cable ties

This cheap radiator mounting kit sourced from ebay has four ties, four springs, four plastic discs and eight adhesive foam pads.

though since you will probably have to fit PC stakes to the board and then solder the wires to those. The mounting holes are too small for anything but the thinnest copper wire to be fed through.

All the wires soldered to the board had external connectors to make removing the module easy (for maintenance). The two battery wires go via a water-resistant SAE plug and socket, the NTC thermistor wires via a 2-pin waterproof plug and socket set and the fan wires were crimped and soldered to a Molex socket, to match the existing plug on the fan.

We placed heatshrink tubing over the thermistor and fan wiring and after shrinking it down, injected some silicone into the back of the Molex plug and socket to improve their ability to withstand a soaking.

The silicone was also forced into the ends of the heatshrink tubing to stop water getting inside and possibly entering pinholes in the wire insulation.

Where possible, fit these connectors to the wires after you have figured out where you're mounting the unit and cut the wires to length. Otherwise, you will be left with a lot of excess cabling to bundle up.

Installation procedure

We used our prototype to control a 300mm fan for a water-to-air intercooler radiator on a supercharged V8 engine. This is a worthwhile upgrade for any vehicle with an intercooler which will be driven in traffic. See the separate panel for an explanation of the benefits.

However, this project is just as applicable for normal radiators in vehicles which do not have adequate cooling, for whatever reason and the installation details will be virtually identical.

As you can see from our photos, the new radiator is a "pusher" style which is mounted at the front of the radiator stack. We chose this type for two reasons; one, the intercooler radiator is in front of the main radiator and we wanted fresh air to be forced over it and two, there was already a pair of "puller" radiators mounted at the back of the radiator stack, which you may be able to see if you examine the photos carefully.

In extreme conditions, the front "pusher" and back "puller" fans will work in concert to force fresh air into the front of the first radiator, through the air conditioner condenser and engine radiator and then over the engine itself, where it will tend to be forced out from under the engine bay.

Fan mounting

The first step was to mount the fan on the radiator. This was done using a cheap but effective mounting kit compris-

ing four ties, four springs, eight adhesive foam pads and four plastic discs (see photo opposite).

The ties are a bit like cable ties but they have a flat plate at one end. You thread one of the adhesive foam pads over the tie (the pads have a hole in the centre) and then force the plastic tie between the fins of the radiator, from the opposite side where you want to mount the fan. You then slip a second foam pad over the tie shaft so it's in contact with the opposite side of the radiator.

The tie then goes through the radiator mounting flange and you slip the spring (small end towards fan) and plastic disc over the tie. The plastic disc has a hole in the middle with little teeth which grab the bumps on the tie, giving a one-way ratchet effect. As you pull the tie through the disc, it compresses the spring and foam pads until the radiator is held firmly in place.

The foam pads on either side of the radiator prevent the force holding the fan onto it from damaging the delicate fins. Once the ties have been installed on the four corners of the fan and tensioned appropriately, it's held in place very well and won't budge under normal acceleration, braking and cornering forces.

In our test vehicle, we had very poor access to the back of the radiator; there was around a 10mm gap between it and the radiator behind it at the top, reducing to around 5mm at the bottom. As such, were only able to attach the fan to the radiator at its two upper mounting points.

To compensate, after slipping the two adhesive foam mounting pads between the fan's two lower mounting points and the radiator, we then forced a highly compressed block of closed-cell foam into the gap between the front of the fan motor housing and the plastic cross-member which sits behind the vehicle's front grille.

This holds the fan firmly against the radiator, preventing it from moving forward under heavy braking and takes some of the gravitational load off the two upper mounting points thanks to the resulting friction at the two lower mounting points. So far, this arrangement seems to have stood up to the abuse which results from driving on Sydney's pothole-filled streets.

By the way, when mounting the fan, we made sure it wasn't resting on the oil cooler below; a small piece of foam was inserted between it and the oil cooler while the fan was being mounted and then finally removed, giving around 5mm of clearance, so that it doesn't bounce up and down when going over bumps and damage the oil cooler fins.

Wiring

With the fan in place, we then found a suitable location to mount the control box itself, next to the headlight housing. It was then secure in place by routing some large cable ties through the holes in the box flanges and around nearby anchor points. A piece of foam was wedged under the unit to reduce the vibration transmitted to it while driving.

The fan wiring is simple; having plugged the fan plug into its matching socket, we simply tied both cables to convenient anchor points to stop the wires flapping around. We then used a cable tie to clamp the NTC thermistor lug onto the intercooler radiator right next to the water inlet pipe. While not shown in these photos, we later wedged an adhesive thermal pad between the two to ensure good heat conduction.

With the thermistor wire plugged into the matching

Advanced set-up

Normally, the unit operates with a PWM frequency of 1kHz, a minimum duty cycle of 25% and a maximum duty cycle of 100%. These defaults are stored in the EEPROM of IC1 and so they can be changed if necessary.

The most common reasons to change these are if you are controlling a fan or fans that use brushless (electronically commutated) motors, such as most computer fans, or if your fan won't run properly with a duty cycle of just 25%. In these cases, you might want to drop the PWM frequency or raise the minimum duty cycle respectively.

The set-up for these parameters takes advantage of the fact that normally VR3 is adjusted to give a maximum fan speed control voltage above 1V. That's because the minimum (fan switch-on) control voltage is fixed at 1V so it doesn't make much sense to have the maximum voltage be lower than this. So if VR3 is set to apply a voltage of 1V or below at pin 3 at start-up, this will activate the advanced set-up mode.

If for some reason you want the fan to switch on at full speed, you can set VR3 to give a reading just above 1V at pin 3. However, you will need to be careful to make it high enough to avoid triggering this set-up mode. The actual threshold is close to 1/5th of the supply voltage, so check the output of REG1 and divide by 5 before setting VR3, to be safe.

Selecting the parameter

Follow these steps, based on which parameter you want to adjust.

1) PWM frequency – adjust VR3 to give a voltage at TP3 which is equal to the desired PWM frequency, where 1mV = 1Hz. So for example, adjust for 500mV if you want 500Hz PWM. Connect a 10kΩ resistor across CON3 (or if you have a 10kΩ pot wired across CON3, as described in the testing procedure, rotate it fully anti-clockwise) and apply power.

Wait for at least one second and then rotate VR3 clockwise until TP3 is well above 1V. Then adjust VR2 to give a PWM waveform at pin 2 and check the frequency with an oscilloscope or frequency counter, to verify that it has been set to the correct frequency.

2) Minimum duty cycle – adjust VR3 to give a voltage at TP3 which is equal to the desired minimum duty cycle, where 10mV = 1%. So, for example, adjust for 330mV if you want a minimum duty cycle of 33%. Disconnect the NTC thermistor (or anything else) from CON3 and apply power.

Wait for at least one second and then rotate VR3 clockwise until TP3 is well above 1V. Then re-connect the NTC thermistor or pot to CON3 and adjust VR2 fully anti-clockwise. Wind it slowly clockwise until you get a PWM waveform at pin 2 and check the duty cycle with an oscilloscope or DMM with duty cycle measurement, to verify that it has been set to the correct minimum.

3) Maximum duty cycle – adjust VR3 to give a voltage at TP3 which is equal to the desired maximum duty cycle, where 10mV = 1%. So, for example, adjust for 750mV if you want a minimum duty cycle of 75%. Short out CON3 and wind VR2 a few turns clockwise, then apply power.

Wait for at least one second and then rotate VR3 clockwise until TP3 is well above 1V. Then re-connect the NTC thermistor or pot to CON3 and adjust VR2 fully clockwise. Wind it slowly anti-clockwise until you get a PWM waveform at pin 2 and check the duty cycle with an oscilloscope or DMM with duty cycle measurement, to verify that it has been set to the correct maximum.

Having finished making any or all of the above changes, re-verify that TP3 is set above 1V and you can then go through the normal set-up procedure to adjust VR1-VR3.

Adding a fan to an intercooler

An intercooler is a radiator which cools the air going into an engine. It's normally fitted between a (turbo)supercharger and the engine or in some cases, between multi-stage turbocharger compressors.

It may cool the air directly or there may be a liquid coolant which transfers the heat energy to a second radiator which is cooled by ambient air (which is the case in our test vehicle).

This is beneficial because the (turbo) supercharger has the side-effect of heating the intake air as it compresses it and forces it into the engine. That increases the chance of the fuel detonating, which could damage the engine and it also limits the effectiveness of the supercharger because the hotter air is less dense, partially negating the benefit of compressing it to fit more into the cylinders.

Most vehicles can benefit from improved airflow past the intercooler radiator and that's certainly true in this case. Our test vehicle greatly benefited from fitting a fan on the intercooler radiator, despite the fact that it is mounted in front of the main radiator which already has two high-performance cooling fans on the back.

That's because an intercooler radiator operates at a much lower temperature compared to the main engine radiator; the intercooler is typically around 10°C above ambient compared to around 90°C (absolute) for the main radiator.

Because of the proximity of the two, when the vehicle is stopped (eg, at a red traffic light) or moving slowly (eg, in a queue of vehicles), especially uphill, there is a tendency for heat from the main radiator to "soak" the intercooler, leading to increased intake temperatures, reduced performance and a louder exhaust note.

Once the traffic clears and the vehicle starts moving again, the intercooler gets back to normal temperatures after a couple of minutes but performance suffers until then. And in some cases, you could hit another red light or more traffic before the intercooler is back to its normal operating temperature.

That's solved by fitting an extra "pusher" fan on the front of the intercooler. It only switches on in situations where the normal airflow is not adequate to keep the intercooler in its ideal temperature range and the extra fan-forced air helps cool both the intercooler and also the normal radiator in this situation.

Fitting an electric fan to a normal radiator

You may be aware that most modern cars have electric radiator fans while older vehicles tend to have belt-driven or clutch-coupled fans driven directly from the engine crankshaft.

Some of these older vehicles have a tendency to overheat and in that case, adding an electric radiator fan to replace or complement the existing mechanically-driven fan is an easy solution.

Part of the reason for this is that older vehicles just weren't as well-engineered but also they may not have been designed to sit in traffic for long periods because they didn't have the sort of traffic that we have to deal with these days! The added electric fan will have little effect most of the time but certainly will give you peace of mind in the summer months, especially if you're stuck in a bad traffic jam.

Keep in mind though that if you have an older or classic car that's overheating, it could also be due to blocked radiator coolant passages, a stuck thermostat or some other mechanical ailment.

In that case, it would be better to fix it than to add an electric fan as a band-aid (despite the fact that this may well solve the problem).

socket, again we tied both wires to mounting points on the bumper and chassis to keep it tidy.

That just left the battery wiring. This was routed under the cross-member which supports the radiators and tied to it and the clamp which holds the battery in place. It was then just a matter of removing the inline fuse, fitting the eyelets over the bolts holding the battery clamps on and then fixing them in place using a beryllium copper crinkle washer and brass nut for each terminal.

We made sure these nuts were done up tight, crushing the washers and forming a good electrical contact between the eyelet lugs and battery terminals, before smearing both terminals with petroleum jelly to prevent water from encouraging electrolytic corrosion due to the dissimilar metals used.

It was then just a matter of re-inserting the fuse and the unit was ready for testing and tweaking.

One final comment regarding installation. You will notice that we went to a fair bit of trouble to waterproof our control box, the wiring and the sensor.

Keep in mind that you could easily get a high-pressure jet of water at the front of the radiator when washing the vehicle and that quite a bit of water will enter when driving in a rainstorm at speed. You don't want your electronics to corrode should that water find its way inside.

That's why we earlier suggested also spraying the PCB with a conformal coating – just in case!

Final adjustments

For automotive applications, we recommend setting the low-battery cut-out voltage to between 13.5V and 14.0V. This way, the fan will only run when the engine is running and the alternator is charging the battery.

If you set it too close to 13V then you might find that the fan will try to run sometime after the engine has been shut off, as the battery voltage can "rebound" to a little over 13V once the load on it has dropped to minimal levels – it takes a while for the voltage to settle to the expected 12.9V of a fully-charged, unloaded lead-acid battery after a long drive.

Resistor Colour Codes

	Qty	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	22kΩ	red red orange brown	red red black red brown
❑	1	10kΩ	brown black orange brown	brown black red brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	470Ω	yellow purple brown brown	yellow purple black black brown

If the fan does try to switch on in this condition, chances are it will immediately turn off again because the extra load on the battery will pull its voltage below 13V. This can result in the fan trying to spin up every couple of seconds, despite the hysteresis built into the battery voltage monitoring.

It won't do any harm but it could be a bit annoying if you can hear it happening. In that case, all you need to do is rotate VR1's screw clockwise a little (say half a turn to one turn) to increase the threshold until that no longer happens.

The temperature settings will probably require tweaking too. In our application, we set the switch-on threshold to 40°C and the maximum speed temperature to 55°C, on the basis that we didn't want the fan running all the time on an average summer day (where ambient temperature could easily exceed 30°C) and that if the intercooler is above 50°C, engine performance would start to suffer.

We ended up dropping those temperatures slightly, to around 38°C and 50°C, as this seemed to keep the engine operating in an optimal manner.

If you're fitting the fan to the engine radiator, you will want to use much higher temperatures. You can expect the coolant exiting a fully warmed-up engine to be around 90°C; remember, its boiling point should be above 100°C because of the antifreeze mixed into the water and because virtually all vehicles use a pressurised cooling system to keep the boiling point as high as possible .

So if your temperature sensor is at or near the entry hose for the radiator then you will want to set the fan switch-on temperature somewhere around 90°C.

If the sensor is at or near the exit, it will need to be significantly lower than this. How much lower depends on how efficient your radiator is.

Chances are you will need to take a guess at the initial setting and then adjust it based on your observations while driving. If the fan is running full speed after a normal drive then you need to increase the temperature setting.

On the other hand, if the fan doesn't switch on at all even after a hard drive on a summer's day, you need to lower the setting.

In general, it's probably a good idea to keep the maximum fan speed temperature close to the switch-on temperature because the difference between the coolant temperature in a properly working cooling system and one which is overheating is not huge.

We would suggest setting it around 10°C higher than the switch-on threshold.

You can increase it a bit if you notice the fan speed "hunting" (oscillating) or reduce it if the fan switches on but the coolant temperature still rises above what you would consider ideal, despite having an appropriate fan switch-on temperature.

Controlling computer fans or other fixed installations

While we designed this project with automotive applications in mind, it would also be quite suitable for controlling "muffin fans", as used in computers, or to cool various pieces of industrial equipment, etc. You could even consider using it to control a fan which ventilates your home, basement, roof cavity, etc, or forces underfloor airflow to help prevent stale air and mould buildup.

As long as the fan runs off 12V DC and draws no more than 10A, it will work OK. And you can connect multiple 12V fans in parallel, up to that 10A limit.

The one issue that you will need to keep in mind is that these muffin fans normally use brushless (electronically commutated) motors which do not respond well to high-frequency PWM control. So you will probably need to drop the PWM frequency to somewhere in the range of 50-200Hz.

See the panel titled "advanced set-up" for information on how to do this.

If you're lucky enough to have four-wire computer fans, one of the four wires (the blue one) can be used to provide PWM control.

So in this case, wire up the red, black and blue wires in parallel. Connect red to +12V, black to GND and blue to the negative terminal of CON2. Connect a 1kΩ resistor between the pins of CON2 and the fans should then operate normally at the default PWM frequency of 1kHz. SC

The new intercooler fan was added in front of the radiator since the existing radiator fans were already mounted at the back (just visible near the top of the photo). You need to use a "pusher" fan if it's being mounted on the front. Here you can also see how we mounted the temperature sensor and tied the wiring to nearby structural elements to prevent it from moving while the vehicle is in motion.

Sale ends January 31st 2018.

ALTRONICS

Build It Yourself Electronics Centre®

www.altronics.com.au

1300 797 007

New Year Gear!

Lost your headphone jack?

No worries! These latest release Bluetooth 4.1 wireless earbuds are a great value sports alternative to Apple Airpods. Weighing less than 6 grams they stay in your ear during exercise, are sweat resistant and offer 3 hours of listening time (9 hours total using the included USB charging case.) Includes 6 pairs of ear bud inserts, USB charging cable, removable earhooks and charging case.

BBC micro:bit GO Kit

The BBC micro:bit is a pocket sized codeable computer with motion detection, compass, LED display and Bluetooth on board. Designed to be fun and easy to use for students in coding class rooms. It even connects to Arduino and Raspberry Pi! Includes USB lead and battery pack.

Protect yourself with a dashboard camera.

This high spec recorder captures every minute you're driving in full 1080p HD, plus motion detect and parking monitor modes allow footage recording even when you're not driving! **Features:**

- 2.7" LCD screen
- Selectable white balance, exposure, dynamic range, resolution, audio recording.
- Optional second 720p camera (S 9438 $54.95).
- Optional GPS for Google maps integration (S 9439 $44.95).

Brilliant Battery Powered Work Lights

LED floodlamps coupled with a rechargeable battery offering up to 6 hours use. Includes car charger & plugpack. Great for work sites & service vans.

Weatherproof Solar PIR LED Floodlight

A compact weatherproof motion activated light with two activation modes. Rear facing dim light with front motion activated bright light. Solar powered. 145W x 96L x 75Dmm. 220 lumens.

$29.95 X 2375

Add Bluetooth Audio Instantly!

Adds wireless audio streaming to any 3.5mm input, whether it be your car, your favourite headphones or home amplifier. Internal battery provides 5 hours of listening time and is USB rechargeable. Just 40mm long, weighing a mere 20g!

Two Way Bluetooth Wireless Audio

Transmit audio from your TV to your headphones. Or use it the other way and send music from your phone to your amp. Uses low latency technology so theres no lip sync issues!

4 Channel Wireless CCTV System

Add security to your home or business with our high resolution 4 megapixel (1080p) CCTV pack. Wireless cameras cut down installation time and effort! Pack includes power supplies for each camera, a network video recorder (expands to 9 channels!) and four compact bullet cameras.

NEW Build It Yourself Electronics Centres!

MIDLAND

NOW OPEN!

212 Great Eastern Hwy.

MYAREE

Opens Late January

5A 116 North Lake Rd.

Follow @AltronicsAU

www.facebook.com/Altronics

NEW!

Q 1069 **$199**

It's waterproof! It's rugged! It's built like a tank.

This new meter is built tough with water and dust resistance, plus a impact resistant case for the rough and tumble of every day use in the field. Auto ranging design offers a feature list as long as your arm with a clear large digit backlit display. Includes carry case and test leads. See web for full spec list.

Records 1080p video!

X 4306 **$289**

Get a close up view with a workbench microscope

This high resolution 12 megapixel USB micrsocope allows close up inspection of just about anything! USB PC interface, plus HDMI output for monitor connection. 220x magnification with 10-50mm focal length. 2.4" LCD

Price Breakthrough 40W Soldering Station!

The pefect balance of value for money and features for beginners or cash strapped students and enthusiasts. Slim, lightweight non-slip handle with tip cleaning sponge and iron safety holder. Full range of spare tips also available.

NEW!

$59.95

T 2090

$79.95 T 5018A

Lockable Equipment Case

With customisable foam inner and eggshell foam lid to keep equipment secure and safe. Ext. size: 495x365x128mm.

The All-Rounder Student DMM

The perfect beginner, student or enthusiast multimeter. 12 auto ranging test modes with good accuracy and an easy to read jumbo digit 4000 count screen. Includes test leads.

$29.95 Q 1129

BEEF UP YOUR WORKBENCH WITH THESE DEALS...

SAVE 20%

T 2163 **$59**

Get started in electronics with this handy 20pc kit.

A jam packed starter kit including soldering iron, multimeter, solder sucker, wire stripper, cutters, pliers and more! Ideal for beginners & enthusiasts.

Clean & Revive Small Parts

Our 50W ultrasonic cleaner uses water and household detergent, coupled with ultrasonic waves to clean jewellery, small parts, DVDs etc, without damage - no solvents required. Stainless steel 600ml tank.

SAVE $25

Shifts hard to remove gunk from glasses, CDs, rings, jewellery & more!

X 0103 **$80**

A workbench essential. SAVE UP TO 20%

$13.50	$17.95	$19.95	$69.95
$11	**$13**	**$15**	**$55**
T 2401 25W	T 2405 40W	T 2409 60W	T 2487 50W

Inspect-A-Gadget

USB Clip On 5x Magnifier Lamp

The latest Inspect-A-Gadget magnifier is powered by a USB port and provides a crisp, clear view of your workbench. 430mm long. 1.5m USB lead.

$39.95

X 0435

NEW MODEL!

3 in 1 LED Work Light

Features a mini flood light, top mount spot torch & SOS beacon. Requires 3xAAA batteries (S 4904 2pk).

$10 SAVE $9.95

X 0223

NEW!

$89.95 T 2252

Laser Tape Measure

Great for trades & consultants. Accurate to 2mm up to 30m. Requires 2 x AAA (S 4904 $4.95 4pk)

$18.95

NEW!

T 3132

Bare Conductive® Paint Pen

Draw real circuits on almost any surface! Great for repairs or experimenting. 10ml tube.

~~$44.95~~ **$35** T 2480

T 2451 Add 250ml butane for $7.50

All heat & no flame!

Iroda® Pocket thermo-gun. Great for removing adhesives & paint. 650°C max. Refillable.

Micron® Soldering Iron Sale

An iron for every occasion! T 2401-09 are ideal for general purpose soldering. T 2487 features adjustable temperature for more sensitive work.

~~$24.95~~ **$17** X 0199A

Light up your work space!

Great for work or play. Features 7 light modes. Requires 3 x AAA (S 4904 $4.95 4pk)

POWER FOR HOME OR THE OPEN ROAD!

NEW!

$299

N 1120

120W Portable Folding Solar Power Kit

Going bush? Have power wherever you go on your next 4WD adventure.
This complete power kit includes 120W panel, solar regulator, battery connection cables and canvas carry case. 3 stage solar charger ensures your batteries are alway performing at their peak! Adjustable stand for finding best sun placement. 720x520x70mm (folded).

$469
N 1114 100W

$279
N 1112 50W

NEW!

Portable Fold Up Solar Power 'Blankets'

The perfect go-anywhere power accessory - use it to charge batteries when you go bush! If you don't want a permanent solar panel on your 4WD, car or caravan, this fold up solar blanket is a great option. It includes a regulator and croc clips for direct hookup to your battery.

~~$59~~
$39
N 0704

SAVE $20

5W Solar Charger Module

Produces up to 400mA charge current. Ideal for maintaining a 12V lead acid battery. 465W x 320H.

NEW!
S 2680
$49.95

Smart Battery Isolator

A voltage sensitive relay designed to combine two batteries when charging, isolating each battery when not. Ideal for 4WDs, caravans etc.

$69.95
N 2018
NEW!

Price Breakthrough! 20A Solar Charger

High current solar chargers were once sold for over $200 - these new quality units are less than $100 and feature USB charging and a full LCD readout with essential battery information. Suits 12/24V systems.

Mini Volt Meter

Great way to monitor battery charge voltage. Suits P 0679/81 panel plates.

~~$14.95~~
$11
P 0672

Dual USB Charging Socket

3.1A max output. Suits standard switch recesses.

$24.95
P 0690
NEW!

~~$59.95~~
$47
A 0287A

Lithium/NiMH Cell Charger

With 5V USB output (use charged cells as a power bank). Car & mains use. Suits AAA/AA/C NiMH & 10340 to 26650 lithium.

S 4732 With Tags
$17.95

$15.95
S 4736 Standard

18650 Lithium Batteries

3.7V 2600mAh. Quality Samsung brand cells. Unprotected. 5.2A discharge current. 18.6Ø x 65mmL.

~~$19.95~~
$15
P 1926

USB Voltage & Current Meter

Allows you to keep an eye on the output voltage and current from your USB port when charging.

$24.50
D 0505A
NEW!
$33.95
D 0507A

Super Slim Battery Banks

Instant recharge for your phone. Slimline aluminium design, fits easily in your pocket.
D 0507A: 2A output, 8000mAH.
D 0505A: Single USB 1A output, 4000mAH.

BARGAIN!
~~$11.95~~
$10
M 8628

Triple USB Car Adaptor

4.2A 5V DC output. Three outputs for charging multiple devices at once.

$10
Z 6338
33% OFF!

DC-DC Converter Module

Allows a low input voltage (3.5-35V) to be increased to a higher output (5-25V). Easy to connect.

SAVE $40

Lithium-Ion Car Jump Starter

Suits 12V battery vehicles. 20000mAh rated battery provides up to 1000A peak output when cranking. Two USB ports are provided for charging devices (like a giant battery bank!). It also has a super bright 1W LED torch in built. Dimensions: 178L x 84W x 45Dmm.

M 8195A

$159

SAVE 22%

Multi-Stage Weatherproof Vehicle Battery Chargers

Each model utilises a microprocessor to ensure your battery is maintained in tip-top condition whenever you need it. Helps to extend battery service life. Suitable for permanent connection. Great for boats, caravans & seldom used vehicles.

$99
M 8534 6/12V 4.5A 7 Stage

$195
M 8536 12V 10A 10 Stage

NEW!

$64.95
M 8881

Charge EIGHT USB devices at once!

Got a family full of devices? This handy charger outputs up to 12A or charging current to keep all your tablets and phones juiced up! Includes power cord.

$19
~~$29.95~~
P 8134

Easy Energy Usage Monitoring.

In-built energy meter to calculate running costs! Can be switched between energy saving (which reduces standby power use) or standard powerboard. Surge protected up to 30000A!

$10
Z 6544
SAVE 23%

Run 5V circuits from two AA batteries!

Boosts the voltage output of two AA batteries to 5V - suitable for powering shields, sensors and controllers.

Long Life Lithium Batteries

Ideal for high power devices. Not rechargeable. Price per two pk.

$4.95
S 4904 2xAAA
S 4906 2xAA

TOP VALUE!

DESIGN & BUILD IT YOURSELF.

Z 6510

2.8" Touchscreen Shield

A 240x320px touchscreen shield for Arduino utilising the ILI9325 chipset. 3.3V input.

Z 6315

165pc Arduino Parts Pack

Includes a huge array of sensors, parts, LEDs, jumper wires, even an LCD screen!

Relay Modules For Automation

10A rated relays with 5V DC coil. Suitable for controlling AC/DC signal.

Model	Relays	Normally	NOW
Z 6325	1	$4.95	$4
Z 6327	4	$12.95	$10
Z 6328	8	$19.95	$15

P 1012A 1660 Hole

P 1015A 2309 Hole

Breadboards for big designs!

Huge breadboards with aluminium bases for those designs that are beyond the scope of your average breadboard!

Z 6347

ESP32 Wi-Fi/ Bluetooth/BLE Module

Provides 2.4GHz Wi-Fi and bluetooth on board for projects requiring wireless control/ data transfer. Requires SMD soldering for assembly.

P 1014A 140pc

P 1018A 350pc

Prototyping Wire Packs

Handy packs of pre cut and trimmed solid core wire for breadboarding your next design!

Acrylic Sheets

New coloured 3mm acrylic sheets to feed to your laser cutter. Make your own enclosures and more! 199x199mm.

- H 0725 Clear.
- H 0726 Red Trans.
- H 0727 Blue Trans.
- H 0730 White
- H 0731 Black
- H 0732 Yellow

Tinker Part Pack

A huge assortment of parts for experimenting and building. Includes diodes, LEDs, switches, resistors, caps, strip board, a motor & more. **Normal RRP value $55!**

K 9640

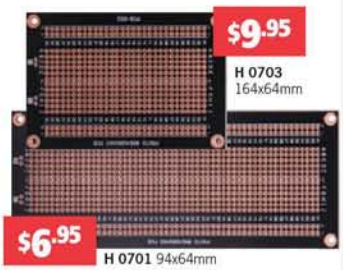
Rare Earth Magnets!

After massive customer demand we've found a source of quality rare earth magnets. T 1464 has 4.5mm countersunk hole.

Model	Type	RRP
T 1464	25x5mm Countersunk	$10.95
T 1465	25 x 5mm Solid	$9.95
T 1466	10 x 3mm 4 pack	$7.95

Breadboard PCBs

Allows you to keep the same PCB layout as your breadboard design. Solder masked & screened. Power rails run the length of the board.



K 9675

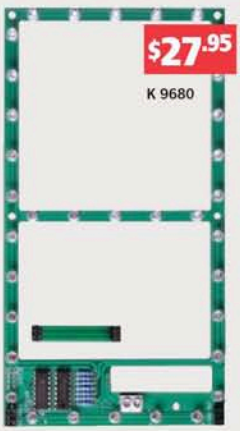
MegaStand Acrylic 16x2 LCD UNO Kit

A cut down MegaBox which provides a backlit 16x2 LCD for simple readouts, plus room to customise the front panel with buttons or IR sensor. UNO (sold separately) fits neatly behind the screen and provides room for add-on shields as required.

K 9670

MegaBox Kit For Arduino

The MegaBox allows an Arduino UNO or Mega to be plugged into it, along with a shield allowing you to build a design into a finished case. Plus it also features a 16x2 LCD, four buttons, rotary encoder, dual 2A 5V relay outs. All pins broken out to headers for connection to breakouts.



K 9680

K 9680

7 Segment Driver Shield Kit

Ideal for Arduino clock/counter control. Features two on board 74HC595 chips which can be easily driven using Arduino ShiftOut.

Build your own jumbo clock or counter

This handy kit makes one 210x110mm digit and can be paired with additional digits to create a clock, number counter etc. Red high brightness LEDs. Driven by Arduino ShiftOut.

K 9805

Heart Rate For Arduino Kit

(DIYODE Nov '17) A simple kit design for biometric Arduino projects - or anything where measuring a heartbeat is required. Requires 9V battery (S 4970B $3.95)

K 9800

Simple Logic Probe Kit

(DIYODE Oct '17) A simple 3 state logic probe for diagnosing circuits, checking output pins etc. Includes test clip connection lead.

B 0092

Sale Ends January 31st 2018

Phone: 1300 797 007 Fax: 1300 789 777

Mail Orders: mailorder@altronics.com.au

Find your nearest reseller at: www.altronics.com.au/resellers

Please Note: Resellers have to pay the cost of freight and insurance and therefore the range of stocked products & prices charged by individual resellers may vary from our catalogue.

© Altronics 2017. E&OE. Prices stated herein are only valid until date shown or until stocks run out. Prices include GST and exclude freight and insurance. See latest catalogue for freight rates.

nRF24L01+ 2.4GHz Wireless Data Transceiver Modules

This month we're looking at a number of modules based on the nRF24L01+ chip, a complete wireless data transceiver capable of up to 2Mb/s over modest distances, in the 2.4-2.5GHz ISM (industrial/scientific/medical) band. It has a standard SPI interface, making it easy to use with any microcontroller.

Connecting a couple of Arduino, Micromite or other popular micros via a wireless data link, can be done by making use of a pair of low-cost modules, based on Nordic Semiconductor's ultra-low power nRF24L01+ chip.

There are quite a few of these modules around, most of them costing just a few dollars, with the more expensive units generally giving longer range (often due to a better antenna).

We published a Circuit Notebook entry in the September 2016 issue titled "Ultra-low-power, long-range Arduino communications", which you can read online at **www.siliconchip.com.au/Article/10146**

This circuit used an nRF24L01+ module, available with a whip antenna, from **www.siliconchip.com.au/Shop/7/3979**

All modules based on the nRF24L01+ device operate in the internationally unlicensed 2.4-2.5GHz ISM band and use the same kind of modulation, described below. So they can all communicate with each other.

It's important to realise that the 2.4-2.5GHz band is also used by Bluetooth devices, most WiFi devices and is also subject to various sources of noise like microwave ovens. We have directly observed serious WiFi speed degradation while a microwave oven was operating, so this isn't just a theoretical issue.

Because it's basically a "free-for-all", this is a noisy band and becoming noisier all the time. Still, there are ways to minimise the risk of interaction and interference, as we'll explain later.

While you may not have heard of Nordic Semiconductor before, many of their chips are found in all kinds of common devices like non-Bluetooth wireless PC peripherals such as keyboards and mice, gaming controllers, sports and fitness sensors, toys and set-top box wireless remote controls.

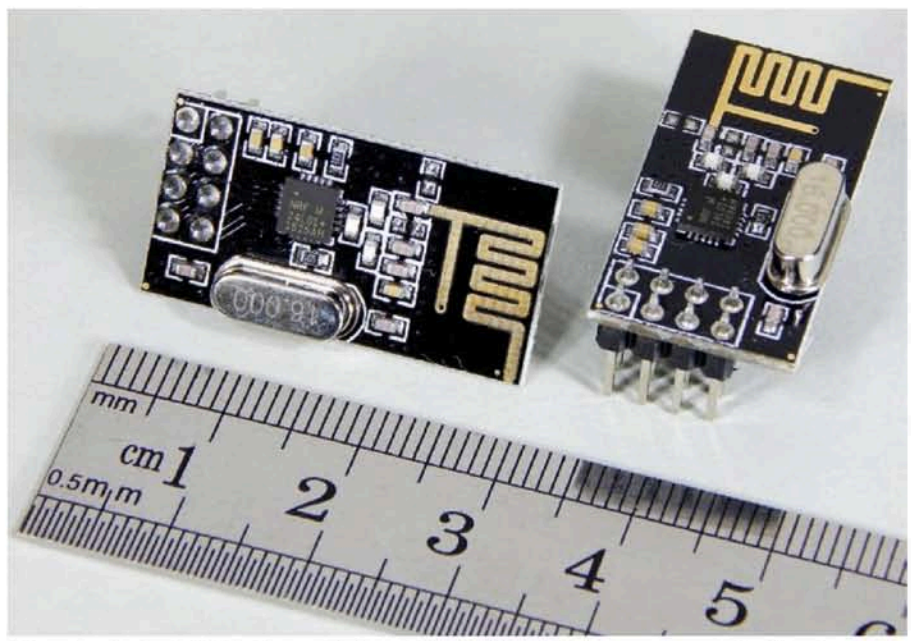
Based in Trondheim, Norway, Nordic Semiconductor was established in 1983 as a spin-off from the Technical University of Trondheim. It's now a publicly listed global Norwegian company with full ISO 9001:2008 certification.

Inside the nRF24L01+ IC

Essentially, the nRF24L01+ is a complete single-chip 2.4GHz wireless data transceiver in a 20-pin QFN (4 x 4mm) package.

Fig.1 shows a block diagram depicting the internal circuitry of the nRF24L01+ chip, on the left, while that of the additional circuitry used to augment performance in the higher-power modules is shown on the right. For the present, let's just concentrate on the left-hand side.

On the left is the baseband section which provides a full bi-directional SPI (serial peripheral interface) port plus an embedded "protocol engine" (using Nordic's "Enhanced ShockBurst" technology), transmit and receive data FIFO (first-in, first-out registers/memory buffers), a radio control section and an array or "map" of control and configuration registers



The simplest nRF24L01+ module, with its circuit diagram shown in Fig.2. Variants of this module might instead have a slightly different antenna track or SMA connector for an external antenna,

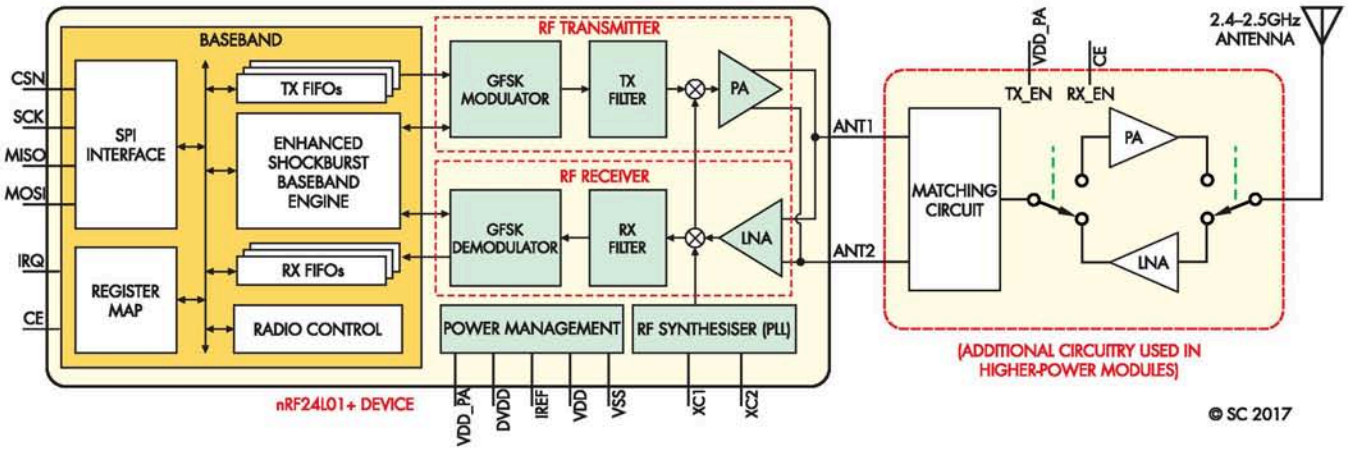


Fig.1: the internal block diagram of the nRF24L01+ IC to the left, with the additional circuitry used for performance improvements in higher-power modules shown at right. The chip also includes a feature called Enhanced ShockBurst, which implements a bidirectional data communication protocol that is primarily used for transferring data between two of Nordic's nRF51 chips (Bluetooth & 2.4GHz) or between an nRF51 and nRF24.

On the right is the RF section, which includes an RF transmitter and receiver plus an RF synthesiser, a power amplifier (PA) and a low noise amplifier (LNA) for signal reception.

The chip's SPI interface allows it to be controlled by a micro while the Enhanced ShockBurst baseband engine provides a range of packet data communication protocols, from manual to advanced autonomous operation.

Basically, it handles all of the high-speed link layer operations. The two FIFO buffers ensure a smooth data flow between the RF front end and the microcontroller (via the SPI interface), in both directions, storing data until it can be processed.

The RF sections employ GFSK modulation, which stands for Gaussian Frequency-Shift Keying, an enhanced form of frequency-shift keying in which the modulating data is passed through a Gaussian filter to make the transitions smoother, before modulation.

This reduces sideband power and cross-channel interference, at the cost of increasing inter-symbol interference, which effectively limits the maximum data rate to about 2Mb/s.

GFSK was the original type of modulation used in Bluetooth and is still used in BR (basic rate) Bluetooth devices.

The nRF24L01+ can operate at data rates of 250Kb/s, 1Mb/s and 2Mb/s, although the 2Mb/s rate is not compatible with devices based on the earlier nRF24L01 chip.

The transmitter is also programmable in terms of output power, with four options available: 0dBm (1mW), -6dBm, -12dBm or -18dBm (320µW). This makes the chip very suitable for ultra-low-power wireless links.

The RF sections of the chip can be programmed to operate on any of 125 frequency channels between 2.400GHz and 2.525GHz, with the channels spaced 1MHz apart. However, the channels above 2.500GHz are strictly out of the ISM band, leaving only the lower 100 for legal use.

In addition, since WiFi devices use the spectrum between 2.400GHz and 2.484GHz fairly heavily, modules using the nRF24L01+ are best programmed to use upper channels 85-100 to ensure minimum interference and the most reliable operation.

Also note that when the nRF24L01+ is being used at the highest data rate of 2Mb/s, it can only use every second 1MHz channel because the modulation bandwidth is larger than 1MHz.

The selected channel frequency is generated by the RF synthesiser section at lower right in Fig.1, using an external 16MHz crystal connected between pins XC1 and XC2.

Despite its internal complexity and multiple functions, the chip is surprisingly economical in terms of power consumption.

Operating from a 3.3V DC supply, the RF transmitter section draws only 11.3mA when set for the highest 0dBm output power, while the receiver section draws only 13.5mA when receiving at the highest 2Mb/s data rate and drops to 12.6mA at 250Kb/s.

So the nRF24L01+ is suitable for all kinds of portable and battery-powered applications, especially since the chip is inexpensive.

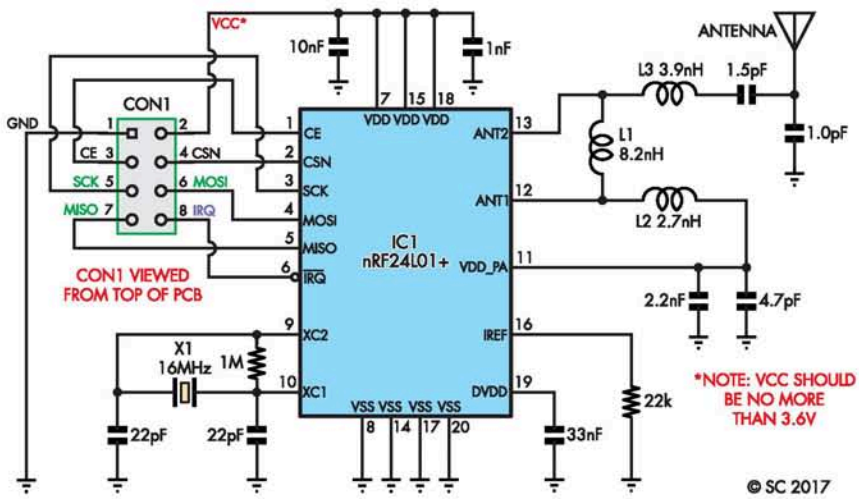


Fig.2: circuit diagram for the NRF24L01+. All connections are made via an 8-pin male header (CON1) which carries power and SPI connections.

One of the fancier nRF24 modules that sports a reverse-SMA socket with whip antenna and three extra SMD ICs to boost RF signals. This module uses a combination of a TI CC2500/ CC2530 and SI4432, but not all modules will use the same set.

Complete modules

Quite a few wireless data transceiver modules based on the nRF24L01+ chip are currently available, falling into two main categories:

- Those using only the chip itself together with a handful of passive components;
- and those which provide one or more additional ICs to give higher RF output and additional receiver preamplification, for longer range operation.

The basic types are the cheapest and most popular but the higher-power types are also quite widely used.

Fig.2 shows the complete circuit for one of the basic modules. This module is quite small, measuring just 15 x 29mm, including both the 8-pin DIL header for SPI and power connections and the zig-zag PCB track antenna.

There are other variations of this basic module which may have a hook-shaped PCB track antenna instead of the zig-zag pattern. Jaycar have this latter module (Cat XC4508).

These have a slightly longer PCB, measuring 15 x 33mm. Yet another variant has an SMA socket for connection to an external antenna (instead of the PCB track antenna) on a smaller PCB measuring 10.6 x 23.8mm.

There's very little in one of these modules apart from the nRF24L01+ chip itself. The 16MHz crystal (X1) is at lower left (in Fig.2), while the 2.4GHz antenna and the passive components used to match the chip to it are at upper right. All of the connections to and from the micro are made via CON1 at upper left. The remaining passive components are mainly for supply bypassing.

Fancier versions

As with the basic versions, there are a number of variations when it comes to the longer-range versions. They all seem to consist of the basic nRF24L01+ transceiver chip coupled to a transmit/receive "front end" circuit, along the lines of what is shown on the right-hand side of Fig.1. The differences are mainly with regard to the IC or ICs used in the added front end and the antenna arrangements.

Fig.3 shows the circuit for one of these augmented versions. The left-hand side is virtually identical to the basic nRF24L01+ module circuit shown in Fig.2 and so these modules generally use much the same software and I/O connections to the micro.

In this particular module, all of the additional RF matching, filtering, transmit/receive switching, power amplification and input preamplification is done inside IC2 (shown on the right).

This is an RFaxis/Skyworks RFX2401C device, rated to provide 25dB of transmit gain at 2.45GHz plus 12dB of receive gain with a noise figure of 2.5dB. Both features should give a very useful extension of the module's operating range.

Some of the other longer-range modules seem to use a combination of three ICs in place of the RFX2401C. Some use the TI CC2500 and CC2530 chips together with an SI4432, but we haven't been able to find a circuit for these.

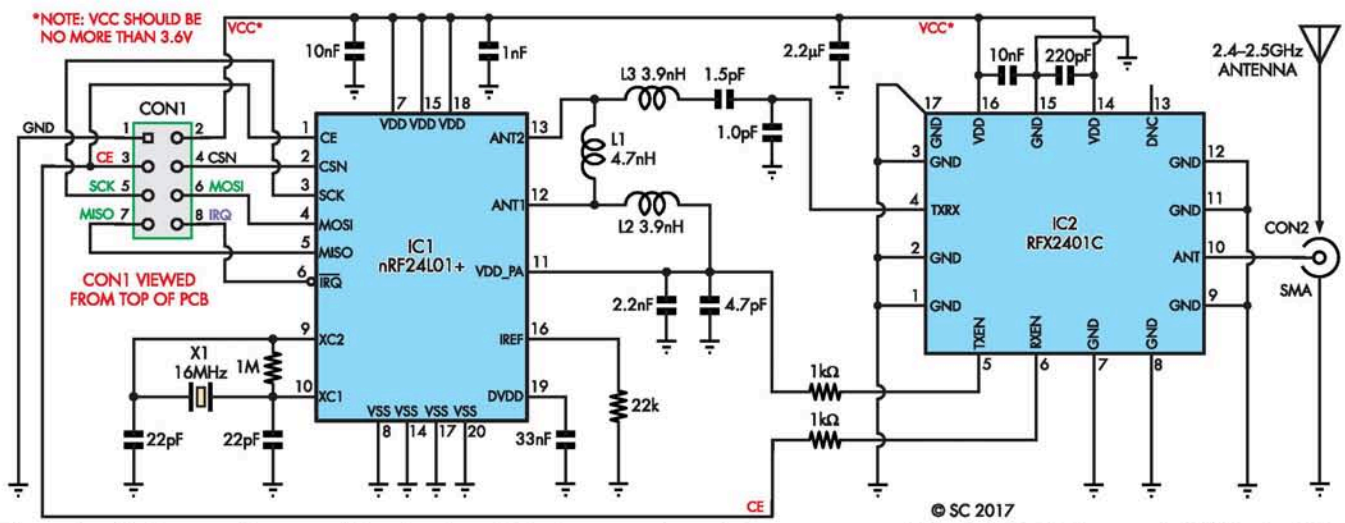
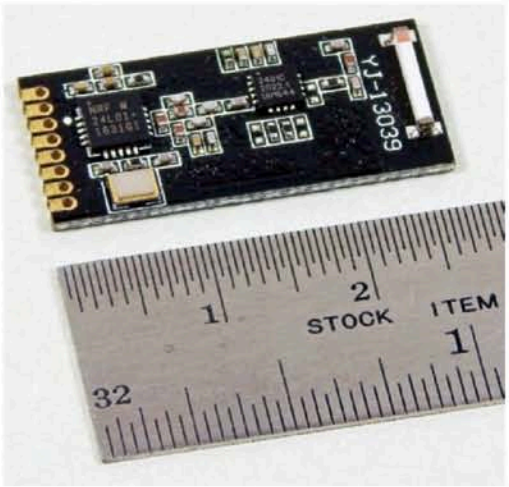
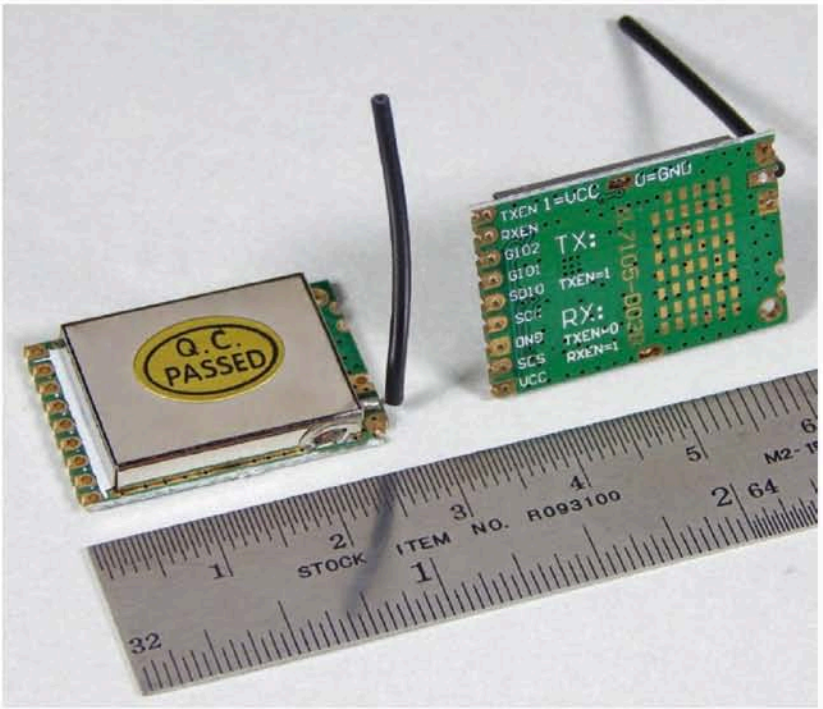


Fig.3: circuit diagram for one of the fancier nRF24L01+ variants (photo at upper right, labelled YJ-13039). While the left half of this circuit may be identical to Fig.2, there is additional circuitry around the RFX2401C (IC2) that sets it apart.





Above: one of the fancier nRF24L01+ based modules featuring a monopole ceramic chip antenna at the end of the PCB. It also has CON1 in the form of a single row of PCB pads.

Right: a different nRF24 module featuring a metal shield around the circuitry to reduce EMI; it also comes with a simple wire antenna.

Although one of the longer-range modules shown in the photos has a reverse-SMA socket for the antenna connection and comes with a matching "rubber ducky" whip antenna, this is not always the case.

Some modules simply come with copper pads on the end of the PCB to either solder on an SMA connector or else have a short piece of wire soldered directly to the centre pad to act as a DIY whip antenna. Still others have a monopole ceramic chip antenna mounted on the end of the PCB. One of these is also shown in the photos.

One further point: most of the modules, whether basic or enhanced, have a copper ground plane on the underside of the PCB (but not under the antenna) to reduce the level of EMI from and into the nRF24L01+ and its associated circuitry.

A small number of the enhanced units also have a screening can over the whole of the circuitry on the top of the PCB and these modules have been found to be somewhat better for reliable long-range operation.

Apparently, some users have achieved similar results with the modules which lack an upper screening can by wrapping the electronics part of the module with thin brass or aluminium metal foil.

The foil should be covered on the inside with a thin layer of plastic to make sure it doesn't cause any short circuits, and should ideally also be connected to the module's PCB earth (eg, via pin 1 of CON1).

Just make sure you don't wrap the foil around the end of the module's PCB with the antenna, or you'll seriously **reduce** its range rather than increase it!

Working with an Arduino

Fig.4 shows how to connect any of these modules up to an Arduino or Arduino clone, taking advantage of the fact that most of the connections needed for interfacing to an SPI bus are made available on the 6-pin ICSP header fitted to most Arduino variants.

The connections to the ICSP header are consistent with many Arduino variants, including Uno, Leonardo and Nano, the Freetronics Eleven and LeoStick and the Duinotech Classic or Nano.

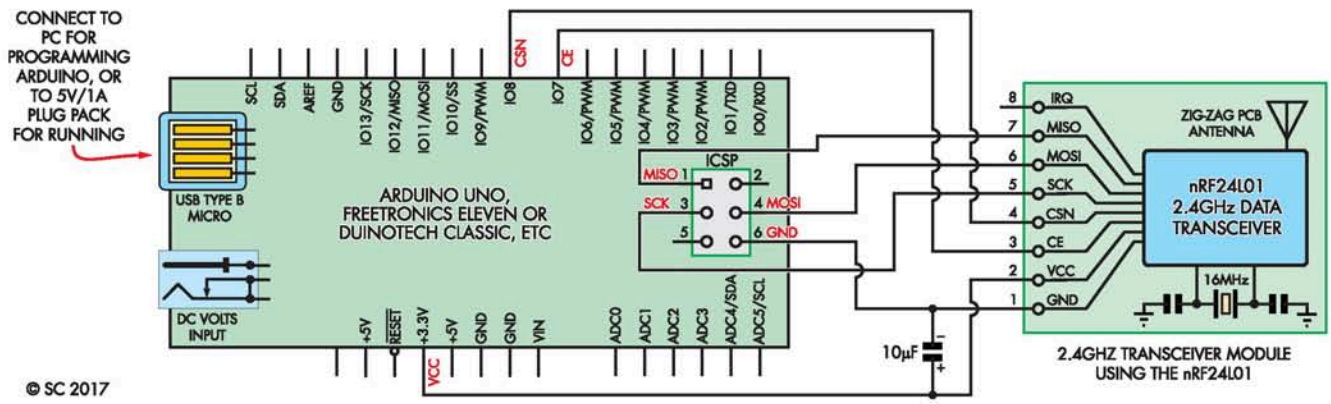
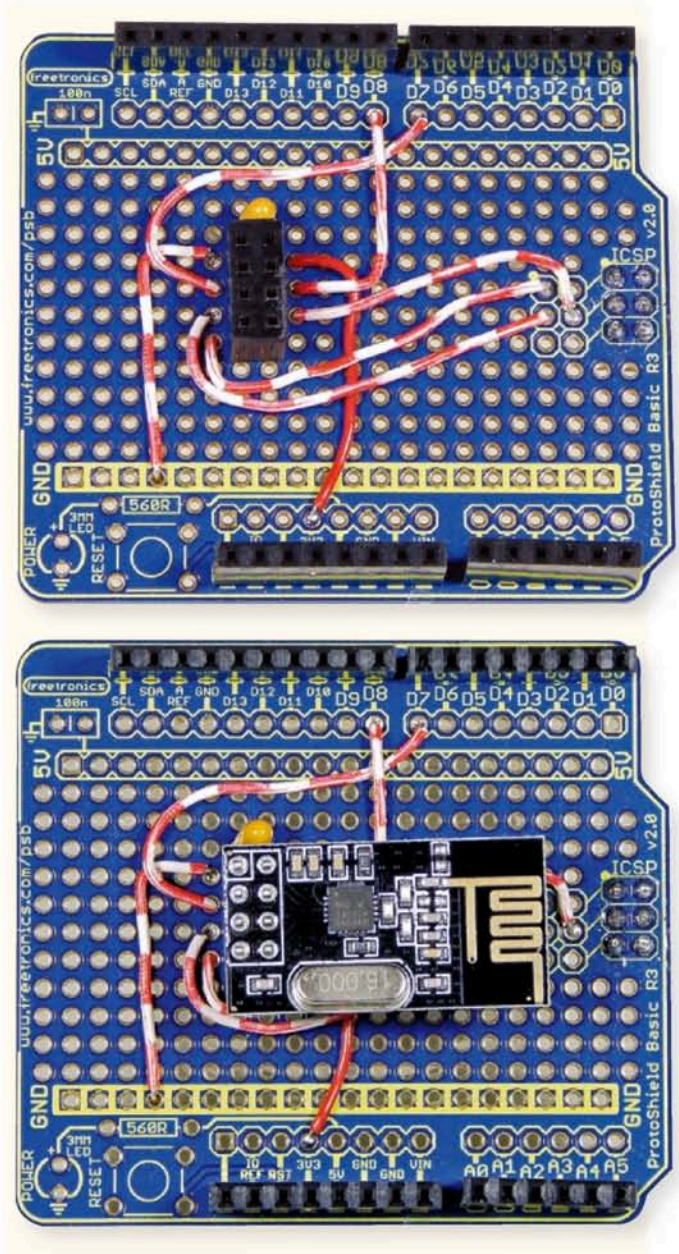
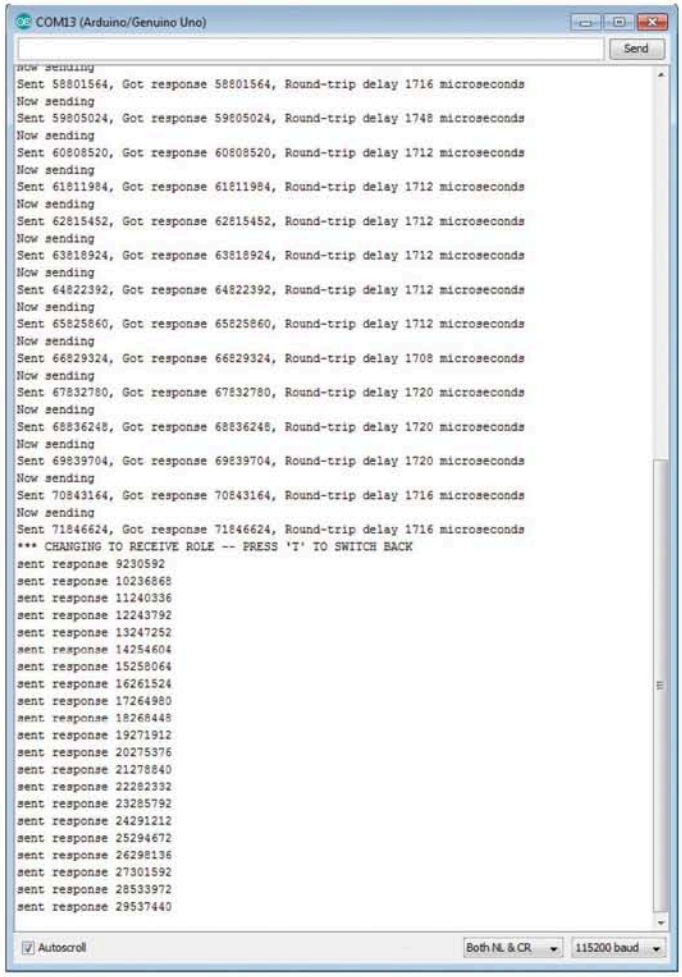


Fig.4: wiring diagram showing how to connect an nRF24-based module to an Arduino board. On the next page there is a photo showing one of these modules hooked up to a Freetronics ProtoShield, which can then be plugged directly into a compatible Arduino board.





Left: you can see the header, 10µF tantalum capacitor and various wires that need to be soldered to the Freetronics ProtoShield that is plugged into an Arduino. The module is then plugged into the 4x2-pin DIL female header.

Fig.5 (above): example output from running the Arduino sample program. The upper half of the screen grab shows one of the modules in "transmit" mode, while the lower half is in "receive" mode.

The only connections that are not available via the ICSP header are those for +3.3V, CE and CSN which need to be connected to the IO7 and IO8 pins respectively.

The reason why they need to be connected to those particular pins of the Arduino is that these are expected by the most popular and easy to use Arduino Library for nRF24L01+ based modules. More on that later.

Before we move on to the firmware, in the photos above you'll see a Freetronics ProtoShield wired up to connect an nRF24L01+ based module to an Arduino Uno or its equivalent.

It's fitted with a 4x2 DIL header socket near the centre of the shield to accept the nRF24L01+ module's plug, with short lengths of hookup wire to make the connections between the header socket pins and the appropriate Arduino pins. The 10µF tantalum bypass is fitted very close to the pin 1 end of the header socket, to keep its leads as short as possible.

This little shield cost less than $5, took very little time to make and works well. Having built it, the next step was to install the RF24 Library in the Arduino IDE.

The Arduino RF24 Library

Written by a programmer with the moniker of "TMRh20", the Library is called RF24. The latest version is available in zipped-up form from https://github.com/maniacbug/RF24 Click on the green "Clone or download" button and then "Download ZIP".

To help you get started using a couple of nRF24L01+ modules to set up a wireless link between two Arduinos, I have adapted one of the "Getting Started" sketches provided by TMRh20 to show how to make use of his/her RF24 library. The revised sketch is called "sketch_to_check_nRF24L01_modules.ino", and is available for download from the SILICON CHIP website.

Having downloaded the RF24 library zip, fire up the Arduino IDE, open up the sketch and then get the IDE to add the RF24 to its list of libraries. This is done by clicking on the "Sketch" drop-down menu, then clicking on "Include Library" down

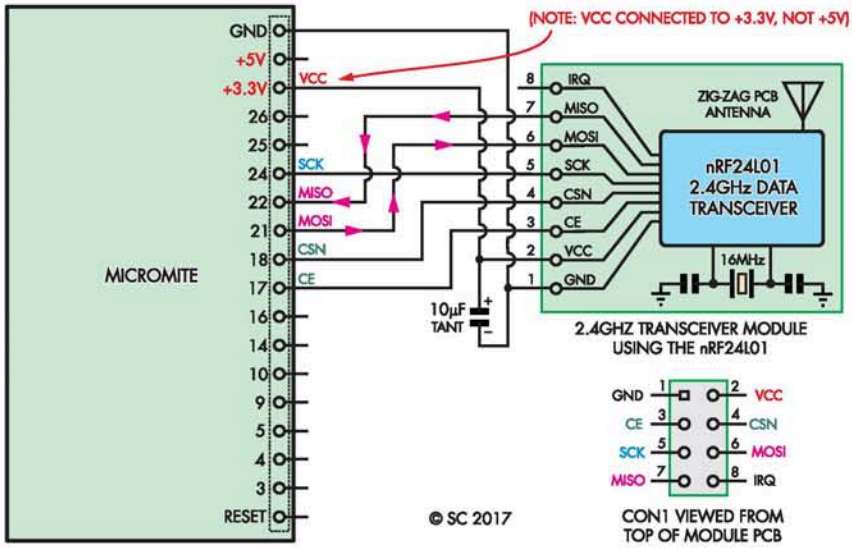


Fig.6: connections required for the NRF24L01+ to a Micromite. The 10µF capacitor between pins 1 & 2 is optional but recommended

near the bottom, and then on "Add .ZIP Library".

The IDE will then provide a dialog to let you select the RF24 ZIP library you've downloaded, whereupon it will automatically unpack and install the library.

The sketch has been written so that it can be uploaded to two Arduinos, one at each end of your proposed wireless link. The only thing that needs to be changed is the value of the parameter "radioNumber", in the first line of code after the introductory comments and the five #include lines. As supplied, the line looks like this:

```
bool radioNumber = 0;
```

but for the second Arduino, it should be changed to:

```
bool radioNumber = 1;
```

Then when you power up both Arduinos (each with an nRF24L01+ module connected), they can communicate with each other. The software is controlled via the Arduino IDE's Serial Monitor utility.

To start one Arduino pinging the other, press the T key on that PC's keyboard, and then the Enter key. That Arduino will then begin sending a number (the time it has been powered up in microseconds) to the other, via the wireless link.

The other should then respond by returning the same number, after a short delay. This should be visible in the Serial Monitor dialog, which should look like the screen grab shown in Fig.5. If you then press the R key, followed by Enter again, the Arduinos should swap roles, with the local one becoming the receiver and the other one becoming the transmitter.

The display in the Serial Monitor dialog should change, as shown halfway down the screen grab, with a series of lines showing when it sends each response back to the other Arduino.

So this sketch shows how a couple of Arduinos can be hooked up via a 2.4GHz wireless link, using a pair of nRF24L01+ based modules.

Doing it with a Micromite

Connecting one of these modules up to a Micromite is done using the connections shown in Fig.6. The MOSI, MISO and SCK lines are connected to pins 21, 22 and 24 of the Micromite as shown. The CE and CSN lines are connected to Micromite pins 17 and 18 respectively in this example. As with the Arduinos, it's also a good idea to connect a 10µF tantalum capacitor between pins 1 and 2 of the nRF24L01+ module.

Now if you're wondering why these SPI connections to the Micromite are a little different from those you've seen in other projects, that's because we're making use of an "additional" SPI port on the Micromite, provided by means of an embedded C function in Geoff Graham's MMBasic.

This is being used as an alternative to the SPI port already built into MMBasic, to prevent timing conflicts when you're using an LCD BackPack version of the Micromite.

The sample program running on a Micromite LCD BackPack. Unlike the Arduino program, setting which device is the receiver or transmitter is done via the touchscreen, rather than serial input.

The reasoning behind this is that there doesn't seem to be available at present any pre-written Micromite applications or libraries available to control and exchange data with the nRF24L01+ chip – so basically, I've had to write one myself.

This took quite a while, as programming the nRF24L01+ turned out to be surprisingly complex and confusing. I ended up having to get help from Geoff Graham, as well as from the support engineers at Nordic Semiconductor.

By the way, if you want to see how complex programming the chip really is, you can download a copy of the 78-page product specification called "nRF24L01+ Product Specification v1.0" for free from Nordic Semiconductor's website (www.nordicsemi.com/eng/Products/2.4GHz-RF/nRF24L01P).

Anyway, I finally got the program to work, with two Micromite LCD BackPacks exchanging data in both directions without problems. Whew!

You can see the display it provides on the Micromite's LCD screen in the photo above, allowing the Micromite to be configured as either Radio #0 or Radio #1; and for either RECEIVE or TRANSMIT. This is configured using the LCD touchscreen, but as with the Arduino sketch, the actual data being transmitted or received is printed/displayed on the PC in the MMChat windows for each device.

The program is not very fancy, but it should at least provide a good starting place for writing more complex programs of your own.

The program is called "nRF24L01 checkout.bas", and is available to download from the SILICON CHIP website.

SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Precision Fridge Door Alarm

Most fridge open door alarms are dependent on sensing the interior light being on to detect a door-open situation.

In our case, the light goes off with the leading edge of the door about 40mm from closed and the most common issue we experience is the door being open much less than this. Even being open as little as 20mm results in too much cold air being lost.

The alarm presented here will sense the door being open less than 10mm. It is designed with a vertical two-door fridge/freezer combination in mind.

This type of combination involves the top freezer door having a reed switch mounted on the bottom of its leading edge, lining up with a circular magnet (approximately 9mm diameter) on the top of the fridge door below.

This gives a precise indication as to whether the door is closed properly.

Because I was primarily concerned with the almost-closed scenario (the fridge is adjusted so the door will close under gravity, so a fully open situation is extremely unlikely).

A pair of normally-open reed switches was used at the rear of the door to permit the leading edge reed to come into play only when the door is within 100-150mm of the closed position.

As the door opens, the magnet on the rear of the door (adjacent to the seal) moves away from the stationary NO reed mounted on the main body and opens the circuit.

This is because, on most fridges, the hinge pivot point is 30-40mm out from the cabinet. See the reed switch layout diagram.

The alarm is based around IC1, a PIC12F683 which runs off two AA cells. A piezo transducer (PB1) generates the alert tone.

Trial and error was used to find the right frequency to drive it using the PWM output on pin 5 of the PIC via P-channel Mosfet Q1. Pin 5 (GP2) is driven low to switch on Q1 and thus apply voltage to the transducer. A 10kΩ pull-down resistor discharges the voltage across the piezo when Q1 switches off.

With the door closed, input pin 2 of IC1 is pulled to ground by the 680kΩ resistor as reed switch S1 is held open by the magnet.

In this state, PIC is in low-power sleep mode with pin 2 set to generate an interrupt and wake the device when it goes high. When sleeping, the current drain is less than 1µA so battery life is close to shelf life.

When either the fridge or freezer door is opened, one of reed switches S2 or S3 is closed and so pin 2 goes high briefly while the door passes through the first 100-150mm of travel.

After that, S1 moves far enough away from the leading edge magnet that it opens and so pin 2 of IC1 goes low again and the PIC goes back to sleep.

On closing, if the door is stopped within the detection zone, pin 2 remains high and a timing process is initiated.

Here the Ultra-Low Power Wake Up function of the PIC is used: pin 7 (GPIO 0) is made an output, turned on and used to charge the 10µF capacitor. To protect this output pin, the charge current is limited by a 220Ω resistor.

After about a quarter of a second, GPIO 0 is then made an input and the PIC put to sleep and it awaits a level change interrupt at GPIO 0. While asleep, the capacitor is slowly discharged via its parallel 470kΩ resistor.

When the voltage at GPIO 0 falls below the threshold for the pin to change digital state, after a few seconds, the interrupt generated wakes the PIC and the program then cycles through to check if the door is still open. If so, it sounds the alarm with two beeps.

The time delay can be extended by pressing the extend pushbutton on pin 4 (GPIO 3). This sets the number of cycles of the ultra-low power wake sequence is required before the alarm sounds.

Since the alarm is only triggered when the door is nearly closed, it is possible to have a shorter time delay than would be required if the door was being monitored at all parts of the open cycle.

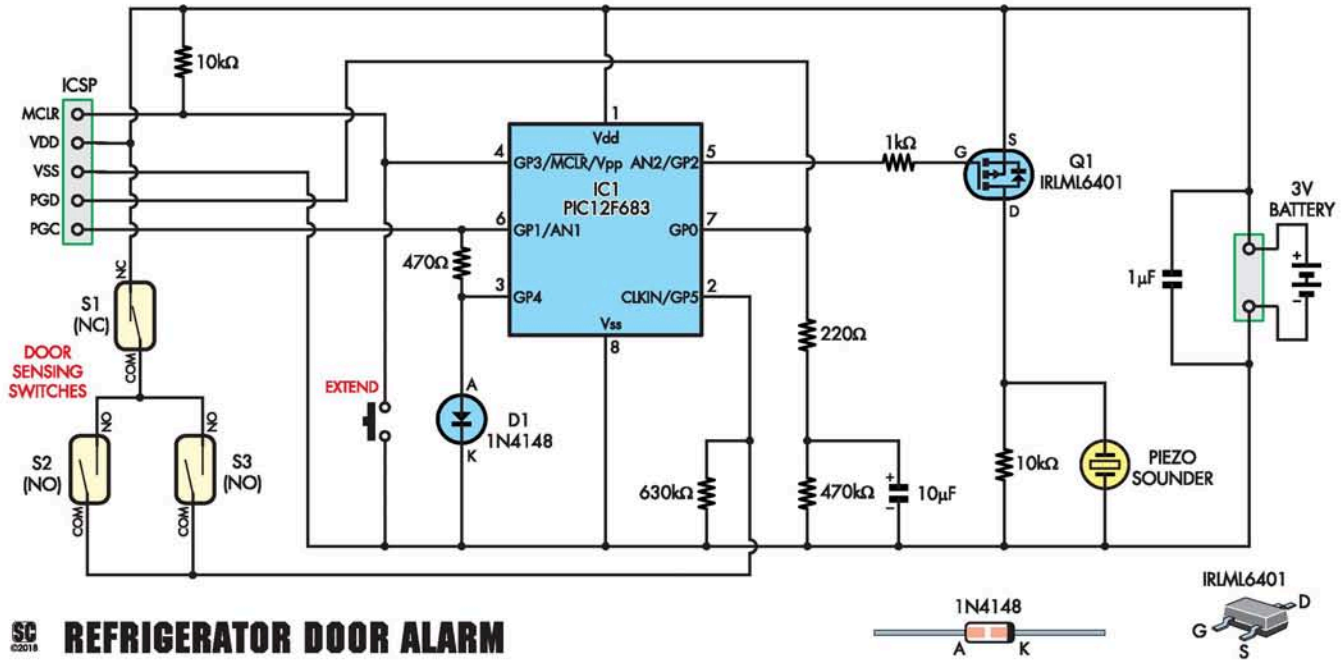
This means that the user of the fridge will not have gone far from the fridge before being alerted that the door has failed to close properly and therefore a quieter sounder can be used. This reduces the chance of others in the house being woken by the alarm at night.

IC1 also checks the battery voltage when pin 2 goes high. A reference voltage is generated by bringing pin 6 (GPIO 1) high, which causes current to flow through the 470Ω series resistor and 1N4148 diode D1 to ground. This generates around 0.65V across D1 which is measured using analog input pin 3 (AN3).

Since the analog-to-digital converter uses the battery voltage as its reference voltage, as the battery voltage falls, the analog reading from AN3 will increase. When this goes above a pre-programmed threshold, a low battery condition is detected: the sounder will then beep three times.

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

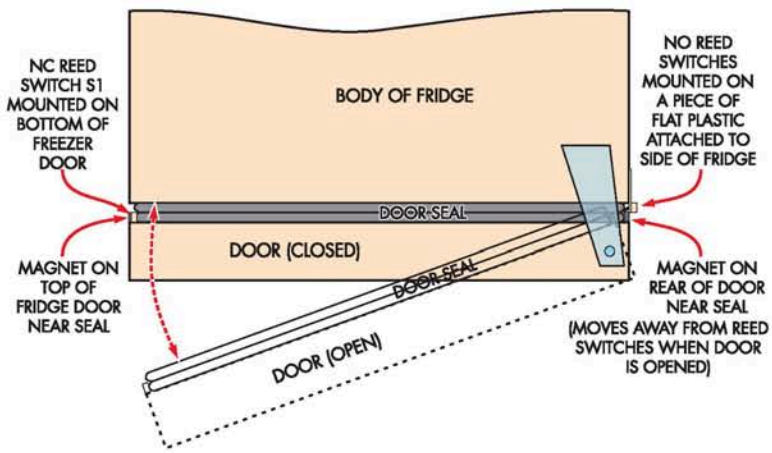


REFRIGERATOR DOOR ALARM

If it was desired to sense whether the door is open in any position then the reed switches at the rear of the door could be eliminated and a longer time delay configured by cycling through the capacitor derived time delay as many times as necessary.

The software was written in C, using Microchip's MPLABX and then uploaded to the PIC using a PICkit 3 programmer via the In-Circuit Serial Programming (ICSP) header provided. Once programmed, disconnect the PICkit to prevent it interfering with the alarm's operation.

Peter Shooter,
Fremantle, WA. ($80)



Debugging a failing electric motor with an RPM and temperature data logger

This circuit was devised to help troubleshoot a large water pump driven by an electric motor which was failing repeatedly.

It had originally been fitted with equipment to constantly monitor the motor RPM and bearing temperatures but that had broken down and nobody could figure out how to fix it. So I came up with this simple Arduino-based circuit to do the same job.

It monitors both the shaft RPM and bearing temperature without needing to be in direct contact with the shaft or bearing.

RPM is measured with an A3144 Hall Effect sensor fixed near the shaft, by picking up pulses as it passes a small magnet glued to the shaft.

Temperature is monitored using a small, low-cost thermopile module which measures the infrared radiation emanating from the bearing or another point of interest.

Monitoring a different part of the motor or pump is simply a matter of pointing the sensor at a different location.

The A3144 Hall Effect sensor can operate from 3.3-24V and works over a temperature range of -40 to +150°C. In this application, we're powering it from the same ~3.3V rail which powers the ATmega328P micro running the Arduino code.

The GY-906 module uses an MLX-90614ESF-BAA infrared thermometer (thermopile).

It can sense temperatures over the range of -70 to +380°C with a resolution of 0.02°C and an accuracy of 0.5°C. It can also run off 3.3V.

Note that the accuracy of its readings will depend on the emissivity of the object being measured.

Black objects tend to have an emissivity close to 1.0 (black body = 1.0) which will give accurate measurements.

Reflective objects tend to have a lower emissivity and so will read as

...continued next page

being at a lower temperature than they actually are.

You ideally need to measure the object of interest directly and indirectly (via IR) so you can calculate its emissivity and correct future IR readings appropriately.

Note also that the IR sensor has a field of view of 70° (you can think of it like a temperature-sensing camera) so, depending on the size of the object being sensed, you may need to place it quite close in order that it responds primarily to the object's temperature and not its surroundings.

Turning to the circuit, the hall effect sensor output is wired to digital input D2 on IC1 with a 10kΩ pull-up to 3.3V.

The software simply counts the pulses per second to determine the shaft RPM. The GY-906 module has an I²C bus so this is wired up to the SDA and SCL pins (27 and 28) of the micro.

A microSD card adaptor is wired up to the SPI bus on the micro, at pins 16-19 and this is used for recording the logged data values.

A DS1307-based real-time clock module is also connected to the I²C bus so that the log entries can be accurately time-stamped.

You will notice that we also have a DS18B20 digital temperature sensor connected to IC1, to I/O pin D7, with a 4.7kΩ pull-up resistor. This provides an alternative means of logging temperature.

For example, it could be attached to the motor housing while the GY-906 IR thermometer measures the bearing temperature.

A 128x64 pixel OLED is also provided and this too is wired up to the I²C bus. This allows you to see live readings so that you can make sure all the sensors are properly attached and working before leaving the unit to log the data.

The circuit is powered by a single Li-Ion cell and its output voltage is dropped via diode D1 to provide close to 3.3V (or possibly a bit higher) to the rest of the circuit.

D1 also provides reverse battery protection while power switch S1 allows power to be saved when the logger is not in use.

We used this device to monitor the temperature of various different bearings over multiple 24-hour periods.

From the logged data, we were able to identify and replace the faulty bearing in our pump, which was getting much hotter (by around 50°C) than the others when the pump was running at higher RPMs, preventing future failures.

Note that we found the GY-906 module to be quite static-sensitive so be careful while handling it or you may damage or destroy it.

Two Arduino sketches are provided for this project. One, called rtc_set.ino is used to set the real-time clock time and date initially.

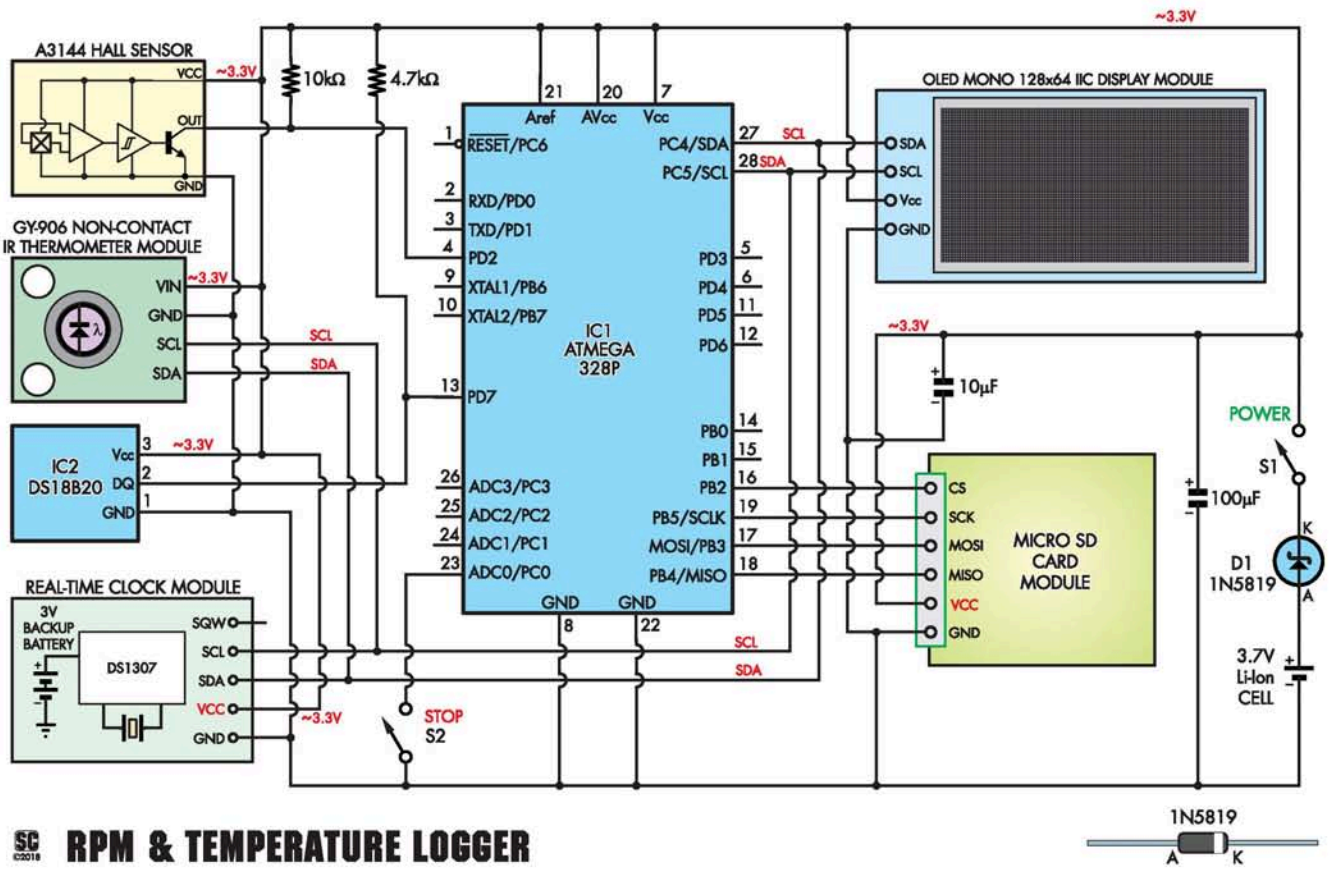
It should then retain these settings using its onboard backup battery and you can load the rpm_recorder.ino main sketch. The download from the SILICON CHIP website (free for subscribers) also includes all the required libraries, in ZIP files.

Note that while the circuit diagram shows a bare Atmega328P micro, you could also use an Arduino Uno or similar micro (which contains the same chip).

If you do decide to use the bare chip, you will have to load the 8MHz bootloader onto the chip before loading the sketch.

See www.arduino.cc/en/Tutorial/ArduinoToBreadboard for more details.

Bera Somnath,
Vindhyanagar, India. ($70)



RPM & TEMPERATURE LOGGER

Op amp antenna preamplifier

Indoor AM radio reception can be poor these days because there are so many sources of interference.

Placing an amplifier near the antenna can help by providing gain for radio signals before interference has a chance to creep in. And when interference does couple into the signal, it will affect it less, due to higher wanted signal levels.

Because modern op amps are available with high gain bandwidths of 100MHz or more, that makes it practical to use them to amplify AM radio signals up to the top of the broadcast band, at around 2MHz.

With a gain of say 20 and a gain bandwidth of 100MHz, it will have an effective bandwidth of around 100MHz ÷ 20 = 5MHz, which is plenty for this application.

The OPA37 used in this circuit is optimised for high gain applications and has a gain bandwidth of 63MHz. It's also a pretty common type with a very low noise figure of 4.5nV/$\sqrt{\text{Hz}}$.

This circuit can be used with a ferrite rod or wire aerial. In the case of a ferrite rod, rotary switch S1 selects from one of three taps on the coil, for reception over a different range of frequencies. VC1 tunes the antenna circuit while rotary switch S2 selects one of five different additional capacitors to change the tuning band.

In the first position, VC2 provides additional fine-tuning capability over the highest frequency band while in the other positions, the frequency range over which VC1 tunes is progressively reduced to provide for lower frequency radio stations (LW and VLW).

Having tuned in a particular signal, it is then fed to non-inverting input pin 3 of op amp IC1 via a 100nF coupling capacitor and 100Ω stopper resistor which helps to filter out unwanted higher frequency signals.

Clamp diodes D1 and D2 protect the input of IC1 from voltages outside its normal operating range, in combination with the coupling capacitor and resistor but they probably won't save it from being damaged by a close lightning strike.

IC1's gain is fixed at around 20.6 times (26.3dB) by the ratio of the 1kΩ and 51Ω resistors. The signal ground reference for this part of the circuit, to which input pins 2 and 3 are biased, is a half-supply rail generated by the pair of 1kΩ resistors connected between pins 7 and 4 of IC1.

This supply rail is bypassed by four capacitors of different values to ensure it's RF grounded and diode D1 makes sure these discharge safely when the circuit is powered down (not through the op amp inputs).

Rotary switch S3 selects one of four different biasing resistor values for input pin 3 of IC1. These affect the Q of the tuned circuit formed by the antenna and the capacitors selected by S2.

Therefore, while S2 and VC1/VC2 select the tuned frequency, S3 controls how wide a range of frequencies are amplified. This is important due to the relatively coarse tuning provided by S2.

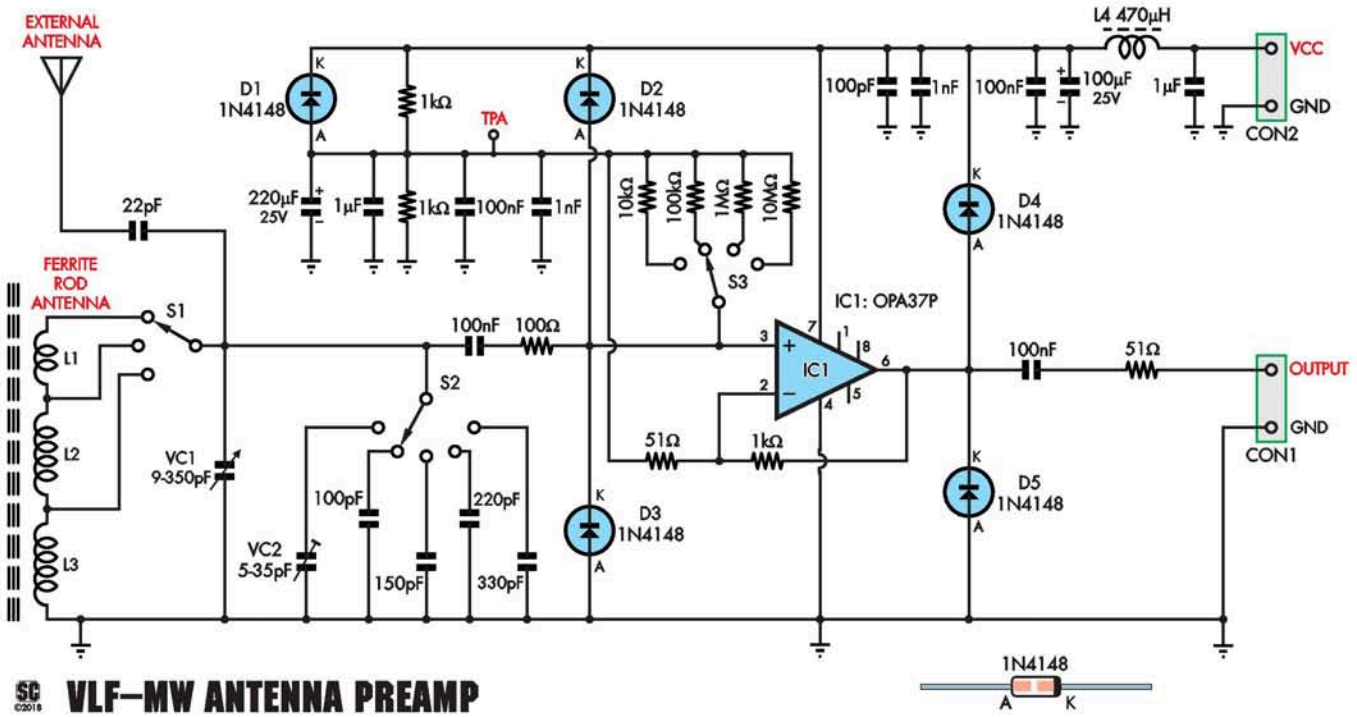
The half-supply DC bias is blocked from the output of IC1 by a 100nF AC-coupling capacitor and a 51Ω series resistor decouples any output cable capacitance from the op amp to prevent instability.

Clamp diodes D3 and D4 prevent inductive spikes or other transients from coupling back through the output cable into IC1 and damaging it.

The power supply is applied via CON2 from a DC plugpack or similar. It can range from 9V up to 44V; 12-15V is ideal. IC1 has four different value supply bypass capacitors to provide good bypassing at a range of frequencies and a 470µH inductor and additional 1µF capacitor form a low-pass pi filter to reject hash from the power supply.

Note that it would be theoretically possible to supply power over the signal cable by removing the 1µF capacitor and wiring CON1 and CON2 in parallel (ie, V_{CC} to Output and GND to GND) but this has not been tested.

Petre Petrov,
Sofia, Bulgaria. ($50)



SC ©2018 **VLF–MW ANTENNA PREAMP**

Vintage Radio

By Associate Professor Graham Parslow

Restoring a pile of hydrated ferric oxide

This was once HMV's C13C 5-valve mantel radio

Why would you want to restore an "unrestorable" radio when you already have a number of similar radios by the same manufacturer and with the same valve line-up? It all comes down to the cabinet. There were so many cabinet styles and colours and some are more interesting than others. And of course, there was the challenge...

The most memorable aspect of this radio was how I came to acquire it. It was on a seller's table at an Historical Radio Society of Australia (HRSA) meeting in Melbourne.

It was late in the day as I passed a table manned by HRSA vice president Mike Osborne. With considerable good humour, Mike solicited me to purchase this radio.

He suggested that I should acquire it as a challenge to my reputation as patron saint of lost-cause radios. As an aside, Saint Jude the apostle is held to be the patron saint of other lost causes.

This radio was so far lost and degraded that the old song "get out of here with that boom-de-boom and take it down below" came to mind. As Mike persisted, the asking price came down until in desperation I was offered $2

You can see above that this shattered Bakelite cabinet looks almost beyond repair, but it hides a chassis that has decayed to the point that it can never be restored.

While shown at right is the underside view of the chassis, with various components having been shed over time.

to take it away. I accepted. True to his word, Mike handed over $2 but I declined and paid him $2 for his hard work in selling the radio.

It looked like a pile of rubbish and it was. The cabinet was badly fractured and that was only the start. And while I had paid the princely sum of $2 for ten minutes of banter with Mike Osborne, I was really just saving him the trouble of carting it home and putting it in the bin. I was certainly not motivated to restore it.

I thought it looked liked a generic no-brand type that various chain stores marketed under brands of convenience, at the time. However, the fluted side moulding on the cabinet did give a stylistic clue that it might be a HMV model.

Just as a matter of curiosity, I sent an email to several HRSA members who might be able to recognise it and sure enough, Jim Eason (HRSA treasurer) came back with the correct identity. Fortunately, a good example of the C13C was shown online in Ernst Erb's Radiomuseum in Switzerland (www.radiomuseum.org).

The radio stayed in the box that I had brought it home in for quite some time before I ventured to have another look at it. Once it was out of the chassis, it was clear that I had purchased a badly deteriorated Bakelite cabinet containing a kilogram or so of hydrated ferric oxide and other debris!

And the reason the ferric oxide was hydrated was that the radio had evidently been partly submerged in water for some years. The water had destroyed every component under the chassis except for some coils and resistors; hardly a good starting point for an electrical restoration.

So the chassis was definitely not a prospect for full restoration and that is an understatement. I have numerous working radios of this general type so I knew what it would sound like. I do have other radios which are far more deserving of full restoration. But perhaps this was a case for a display-only restoration...

But there is a compelling temptation among most radio collectors (myself included) to take a peek at the back of a radio, to see the valves and general layout.

Because of the information on the Radiomuseum website, perhaps I would be able to reproduce labels and add components, to give a cursory simulation of a working radio.

After all, the human eye is easily deceived. We frequently perceive an object as simply another example of something familiar. We fill in details that are not there and we can easily miss anomalies. Film makers and magicians are well aware of this.

In James Cameron's 1997 film Titanic one scene is taken on a deck of the majestic ship but if you freeze the frame and look to the far left, you can see where the mock-up ends and the studio begins.

Few people ever noticed that mis-

The screen-printed glass dial was virtually the only component that survived years of immersion in water. Maybe the mud preserved it.

This is the chassis after it had been washed. Note the remains of the loudspeaker and the exposed windings of the transformer.

take or any of the other numerous visual errors in that film (check them out at https://youtu.be/8-JXpxr0fzg).

And this radio will certainly never pass close scrutiny. I must admit to having serious doubts about whether I could even justify the work required to make it worthwhile as a display-only set when I took it out of the cabinet, as the chassis lay on my bench dropping rust and other miscellaneous detritus. There was virtually nothing that was recognisable on the underside.

The top of the chassis was similarly discouraging. The tuning capacitor had evidently completely dissolved and just a rusty rim was left of the 5-inch Rola speaker.

This shows the chassis after it has been painted, labels added and the loudspeaker replaced. Note the gaffer tape around the base of the first IF transformer, hiding a large hole. It's still a pile of garbage.

But apart from that, most of the components were still there, even though none of them would ever operate again!

As a start, the bare case was thoroughly washed and the lettering "HIS MASTER'S VOICE" emerged from underneath the encrustation of mud. The case had some serious fracturing but fortunately, a large fragment of the missing top section was present as a separate piece. So it was not beyond redemption.

The next step was to cut an aluminium sheet to span the gap, large enough to overlap so that it could be clamped and glued in place with Araldite from below.

This corrected the distortion of the case and provided a base for gluing the large fragment. Then 2-part car body filler was applied to achieve a good surface for sanding back.

This was followed with an undercoat, then a spray with Motortech-brand "Indian Red" paint. The result was similar to the appearance of the original Bakelite case and certainly a miraculous improvement over the initial condition. Some yellow speaker grille cloth and knobs completed the external restoration.

Painting over the defects

The rust-encrusted steel chassis was cleaned up as well as possible but not too vigorously because it was tissue thin in many places. A coating of silver paint (water-based acrylic enamel) restored the appearance of the chassis. A little paint hides a lot defects; well, more or less.

And even though the radio would never be operational, a replacement 5-inch Rola speaker was essential to keeping up appearances.

The original phenolic panel for the aerial and earth connections simply crumbled away due to the adverse effects of water immersion, so I fitted a new set of terminals.

A glance at the photos of the chassis before and after this will reveal the full extent of this superficial restoration to a "static model". Notice the exposed windings of the primary transformer after it had been hosed off.

Perhaps the most remarkable aspect of this story was the screen-printed dial. Once the caked-on mud had been carefully cleaned off, all the station markings were there in their original condition.

Apart from rising to the challenge of restoring this model as a rough-and-ready static model and thereby attempting to maintain my reputation as the patron saint of restorers, er, lost causes, what is the particular interest of this HMV 5-valve superhet radio?

The model C13C is quite similar to mantel radios offered by other manufacturers at the time.

Released in 1951, it has its legacy in the 1940s, both electronically and by way of styling. As an end-of-era example, it merits a place in the history of Australian radio.

Only one IF stage

There are two noteworthy aspects of the circuit shown in Fig.1. First, there is only one IF amplification stage and the tone control is not the usual continuously-variable top-cut type but is a 3-position switch, with "Bass" and "Speech" settings.

On the left-hand side, we see a conventional aerial coil in two sections and a 3-pole switch (S1) provides the

This shows the tarted-up chassis back in the newly painted cabinet. The tuning capacitor for this radio was not replaced as the area where it would sit is still heavily corroded. The 6V6 tetrode output valve (far right) was coloured black using a marker pen to hide the fact that it was gassy.

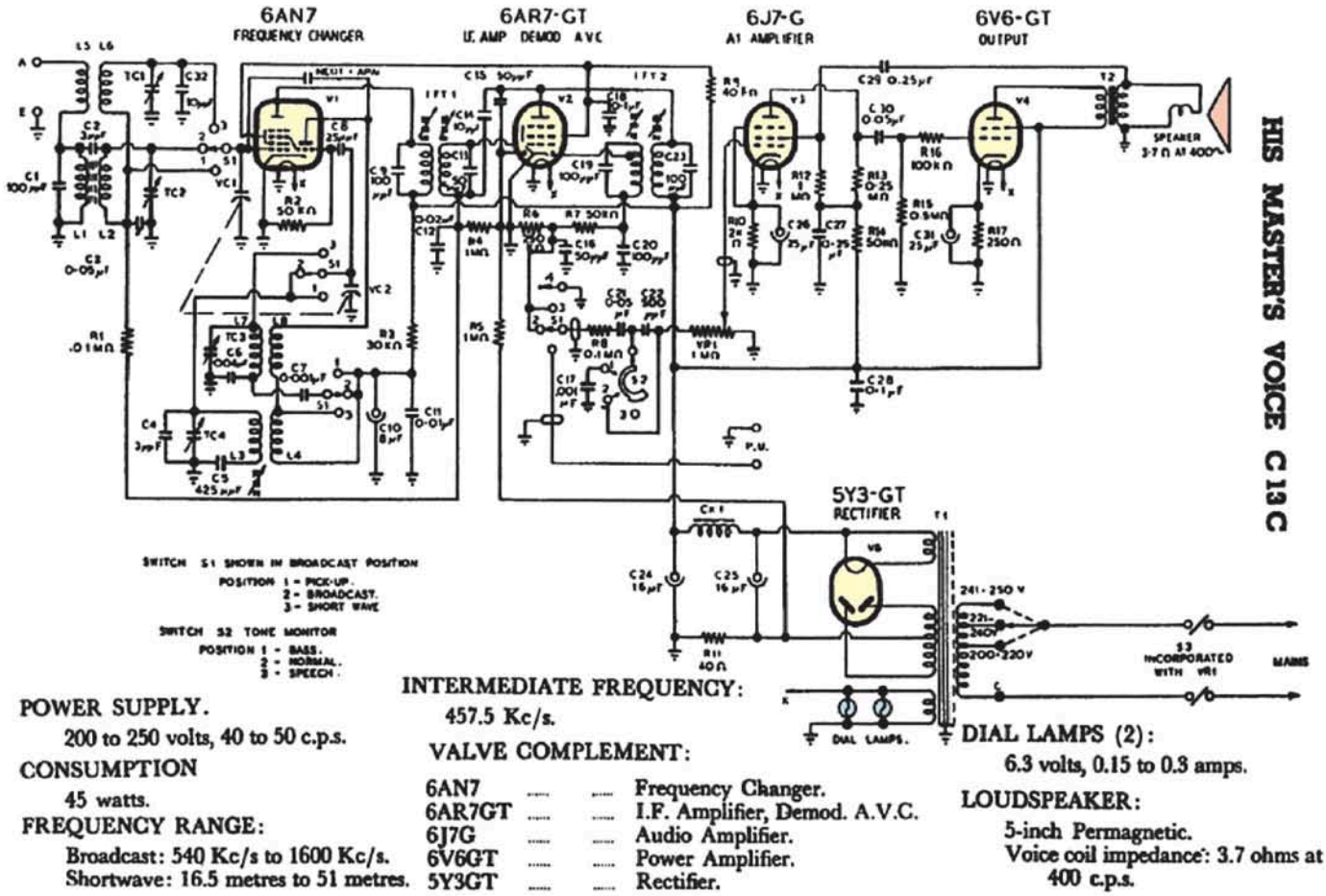


Fig.1: the circuit is quite conventional except that it does not have a variable tone control but a 3-position switch giving "Bass" and "Speech" settings.

Shown above is the freshly painted cabinet and finished restoration for the HMV C13C mantel radio. From left-to-right, the first knob is the band switch, next is tone control and the last is for volume/power.

While not the star of this article, this HMV E43E radiogram used a nearly identical circuit as the HMV C13C mantel radio but was still regarded as hifi. The only difference was that it had a 12-inch Rola loudspeaker.

band switching: medium wave, MW ranging from 540kHz to 1600kHz or shortwave, 16.5 to 51 metres (5.9 to 18.2MHz).

Band switch S1 selects the appropriate secondary winding of the aerial coil to be tuned by the first gang of the tuning capacitor and also selects the coils for the local oscillator.

The only miniature valve in the chassis is the 9-pin 6AN7 as the frequency converter (mixer-oscillator). The other valves are classic octal types (ie, 8-pin with a Bakelite base) with a heritage dating back to the 1930s.

The 6AN7 was released by Philips, Eindhoven as the ECH80 for Europe in March 1949. This 9-pin miniature valve then became a common inclusion for Australian radios of the 1950s. It required 6.3V for the filament at 230mA.

The intermediate frequency (IF) of this set is 457.5kHz. This was fairly common for HMV sets around this time, but most sets of this era would have had a 455kHz IF.

The dial calibration is almost entirely devoted to the MW band which suggests that casual domestic listening was the primary market.

The band change switch also selects the gramophone pickup. When the pickup input is selected (switch 1 position 1), the local oscillator coils are disconnected.

This disables the tuner section to avoid the potential for annoying breakthrough of radio while playing records. The gramophone pickup feeds in through the two central sockets at the rear of the chassis.

It seems the HMV C13C was rarely used with a pickup. In reality, the gramophone pickup connection was a standard feature of the chassis which HMV did use in a wooden cabinet radiogram, model E43E of 1951.

After the 6AN7 frequency changer, the secondary of the first IF transformer drives the grid of the 6AR7 amplifier-demodulator valve. This valve was designed and manufactured by the Amalgamated Wireless Valve Company (AWV). Rather than a typical twin-diode tetrode IF amplifier such as the 6N8, the 6AR7 is a pentode partnered with twin diodes.

The pentode's higher gain compensates to some extent for the lack of a second IF valve. The pentode's plate drives the second IF transformer and there is adequate signal to pass to a

HIS MASTER'S VOICE
— VOLTAGE TABLE. —
(MODELS, D33A, D33B, C13C, E43D, E43E)

- VOLTAGES AND CURRENTS ARE WITH THE RECEIVER OPERATING ON AVERAGE MAINS VOLTAGE, AND TUNED TO A POINT OF NO RECEPTION ON THE BROADCAST BAND.
- VOLTAGE READINGS TAKEN WITH METER RESISTANCE OF 1,000 OHMS PER VOLT.
- VOLTAGE AND CURRENT READINGS WITHIN ±15 %
- RESISTANCE READINGS ARE APPROXIMATE

VOLTS TO CHASSIS	CURRENT M.A.	RESISTANCE TO CHASSIS	VALVE ELECTRODE	BOTTOM VIEW OF VALVE SOCKET	VALVE ELECTRODE	VOLTS TO CHASSIS	CURRENT M.A.	RESISTANCE TO CHASSIS
			V1	6AN7	FREQUENCY CHANGER			
					HEATER	6·3 A.C.	230	——
——	——	NIL	HEATER		INT. CONN.	——	——	——
NIL	9·6	NIL	CATHODE		HEX PLATE	240	2·4	INFIN
——	——	2·1 MEG	CONTROL GRID		OSC PLATE	95	4·6	INFIN
80	2·3	INFIN	SCREEN GRID		OSC. GRID	——	——	50,000 Ω
			V2	6AR7 - GT OR EBF35	I.F. AMPLIFIER — DEMODULATOR — A.V.C			
					GRID	——	——	2 MEG Ω
80	1·1	INFIN	SCREEN GRID		DIODE No 2	——	——	300,000 Ω
240	4	INFIN	PLATE		DIODE No 1	——	——	1 MEG Ω
NIL	——	NIL	METAL SHELL		CATHODE	NIL	5·1	NIL
NIL	——	NIL	HEATER		HEATER	6·3 A.C.	300	——
			V3	6SJ7 - GT	AUDIO AMPLIFIER			
——	——	1 MEGΩ (MAX)	GRID		CATHODE	1·1	0·75	2,000 Ω
1·1	——	2,000 Ω	SUPPRESSOR		SCREEN GRID	30	0·2	INFIN.
NIL	——	NIL	HEATER		HEATER	6·3 A.C.	300	——
NIL	——	NIL	BASE SLEEVE		PLATE	40	0·55	INFIN.
			V4	6V6 - GT	OUTPUT			
240	3·5	INFIN	SCREEN GRID		GRID	——	——	0·6 MEG Ω
222	42	INFIN.	PLATE					
NIL	——	NIL	HEATER		HEATER	6·3 A.C.	450	——
			NO CONN.		CATHODE	10·5	45·5	250 Ω
			V5	5Y3 - GT	RECTIFIER			
246 A.C.	——	240 Ω	PLATE No 1					
					PLATE No 2	246 A.C.	——	240 Ω
260	2 AMP. A.C.	INFIN	HEATER					
			NO CONN		HEATER	260	——	INFIN.

REMARKS :- UNFILTERED H.T. VOLTAGE = 260 VOLTS.
FILTERED H.T. VOLTAGE = 240 VOLTS.
TOTAL H.T CURRENT = 60 MA.
VOLTAGE ACROSS R11 = 2·4 VOLTS.
RECTIFIER HEATER VOLTAGE = 5 VOLTS.

Table 1: voltage table for the valves used in the HMV C13C and various other HMV radio sets.

diode in the 6AR7 for demodulation.

The recovered audio then passes to the volume control potentiometer which is ganged with the mains on/off switch, a common feature of sets of this era. The second 6AR7 diode generates the AGC voltage which is fed to the grids of both the 6AN7 and 6AR7 to reduce gain for high strength signals.

The following 6J7 audio preamplifier pentode and 6V6 beam-tetrode output valve provide an audio section that is capable of producing around 3W from either a crystal gramophone pickup or local radio signals.

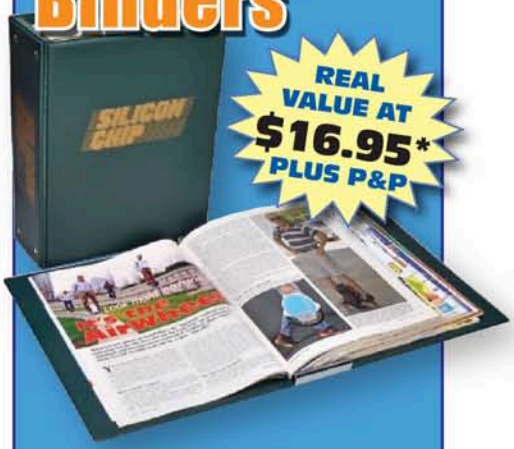
Tone control is by the aforementioned 3-position switch (S2). Its "Bass" setting is simply a top-cut provided by a 1nF capacitor and the "Speech" position is bass-cut by adding a series 0.5nF capacitor to the signal path.

The circuit was basic to several HMV models as can be seen from the voltage table (Table 1) reproduced here that lists multiple models. The table clarifies the function of each valve pin, as well as giving operating voltages and current.

Using the same circuit and chassis as in the C13C, the HMV E43E radiogram was "hifi" in 1951. The only difference was the provision of a well-baffled 12-inch Rola speaker to provide good volume and frequency response.

The HMV radiogram pictured here from the author's collection shows that it was also an elegant item of furniture. SC

Silicon Chip Binders



Are your copies of Silicon Chip getting damaged or dog-eared just lying around in a cupboard or on a shelf? Can you quickly find a particular issue that you need to refer to?

Keep your copies safe, secure and always available with these handy binders

These binders will protect your copies of Silicon Chip. They feature heavy-board covers, hold 12 issues & will look great on your bookshelf.

★ 80mm internal width

★ Silicon Chip logo printed in gold-coloured lettering on spine & cover

Silicon Chip Publications
PO Box 139
Collaroy Beach 2097

Order online from www.siliconchip.com.au/Shop/4 or call (02) 9939 3295 and quote your credit card number. **See website for overseas prices.*

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Confusion building the Super-7 AM Radio

I received the Super-7 Radio PCB recently (www.siliconchip.com.au/Series/321) and I'm a little confused about some differences between the parts list, the overlay and the circuit.

After placing all the resistors as per the overlay I had one left over, 22kΩ. The empty space on the PCB shows 3.3kΩ (at bottom left of battery box), as this connects to the LED. Should this be the 22kΩ resistor, as per the circuit?

Regarding the capacitors, there are five 22nF capacitors on the overlay and circuit but only four in the parts list. Is there a 22nF at the bottom left of the battery holder to make up the five?

The 100µF capacitor shown in the circuit is replaced by a 470µF as per the errata, but where is this on the overlay? Or is it supposed to be a 47µF as per the parts list, in which case, where does it go? (J. S., Strathalbyn, SA)

● As you've surmised, the 22kΩ ohm resistor is for the LED and it goes in the position marked 3.3kΩ. The five 22nF capacitors are 1: above VR1; 2&3: above the 9V battery; 4: above T2 and 5: above Q3. The 470µF capacitor goes to the right of Q7 while the 47µF capacitor is just below TP7.

Super-7 AM Radio queries

I got my Super-7 AM Radio PCB and it looks great in black. My 128mm (125mm) Jaycar-sourced speaker fits; I tried to find a suitable one from Altronics but couldn't. I have noticed a few holes are a little small, eg, the headphone jack, volume control lugs and battery holder mounting screw holes. It seems I will have to enlarge them to make them fit.

Why didn't you include FM reception as well as AM?

By the way, I think there is a typo in the parts list; it specifies BAT56 diodes which don't exist but the circuit diagram shows BAT46 which do. Can I use a germanium diode in place of the BAT46? Would it be better or not much difference? I cannot wait to get it up and running. Thanks for an interesting project. (R. S., Epping, Vic)

● We believe the holes in the PCB for the headphone jack and volume control are correct to suit the specified parts. The mounting screws for the battery holder are self-tapping so these holes will open out slightly when the screws goes in.

If you do enlarge holes, check if the pad is connected to a track on the top side and if so, make sure that you solder both sides of the pad (ie, top and bottom).

Adding FM would have greatly complicated the design and it was intended for constructors to understand AM radio operation and to produce a retro AM radio. AM radio of that era was around well before FM radio was introduced.

You are right that it should be BAT46; not BAT56. The BAT46 can be replaced with a germanium type but it won't make any difference to the sensitivity. Note that the speakers Jaycar stock now are different but still has a 100mm driver and the new ones do fit on the PCB. The PCB allows for many types of 100mm speakers including higher quality types such as those for intended cars with a single or dual cone.

Suitable speakers for Super-7 AM Radio

I am gathering parts for the Super-7 transistor radio project and I am finding it difficult to source a similar speaker to that shown in the article. All of the local suppliers can give me a 4-inch round speaker but they have square surrounds with their mounting holes on this square outer.

Could you please advise where you sourced your speaker. I have already ordered the PCB and case parts. (P. C., Woodcroft, SA)

● We bought two Jaycar AS3008 4-inch speakers which are not identical. You can see photos of the one we used in the article (it's round) while the other looks like the one in their recent catalog and is more rectangular. So they must have changed their stock. The newer AS3008 does fit on the AM Radio PCB. Alternatively, you could use a 4-inch car radio speaker, provided it will fit.

Unexplained extra resistor in regulator kit

I recently called your office about the Jaycar KC5501 kit I am building that's based on your Universal Regulator Board, published in the March 2011 issue (siliconchip.com.au/Article/930).

The kit included different value resistors for whichever voltage it was going to be running on and three spaces on the board marked for resistors labelled as R1, R2 and R3. I installed resistors R1 and R2 as the instructions said but nowhere in the booklet was any information on what resistor is to be placed in R3.

I called SILICON CHIP and asked about this and was told that there was no such resistor R3 in the design as published.

On my board, it's placed vertically between the four diodes and the two larger capacitors. I was told that it was safe to leave it out, so I did.

When I had the finished power supply professionally wired and connected to a mains outlet, the diode marked as D3 cracked and smoke started to pour out. This may be due to my skills as an amateur circuit board builder but I'd like to know what happened with resistor R3. (L. F., via email)

● The Jaycar kit seems to have an extra LED (LED3). This LED connects between the inputs to the two regulators via R3 (and LINK1 if required). For the kit you built, where a dual supply is used, R3 should be about twice the resistance value of R1 or R2.

Note that since the regulator input voltage that powers LED3 is greater than the regulator output (REG1 that

GPS baud rate incompatibility in frequency standard project

I have just finished building the GPS-based Frequency Reference (March-May 2007; siliconchip.com.au/Series/57). When switched on, the display comes up with zeros and the 1Hz LED flashes. Pressing the location button changes the screen to Latitude & Longitude but again, all zeros.

I am using the V.KEL GPS receiver module and this locks to the GPS satellites after a minute or so, when outside. There is a 1pps pulse coming out of the GPS module and also data coming out of the TX pin into the PIC pin 7 but nothing coming out of the PIC pin 8 back to pin 1 of the GPS module.

By mistake, I wired these two pins the wrong way around to start with and wonder if I have damaged the PIC. Also, there doesn't appear to be any error pulse going into pin 9 of the PIC.

To date I haven't tried to set up the rest of the circuit but I do have the approximate frequencies coming out at the appropriate places which is a good start.

I have also used a different display as I had them in stock. They have 16 pins along the top instead of the two rows of seven pins, as you described. (J. H., via email).

- Since you write that there's a 1pps pulse coming from the GPS module and NMEA data coming from the module to pin 7 of the PIC, that suggests that basically all is well regarding the GPS module itself.

Don't worry about the lack of signal coming out of pin 8 of the PIC though; normally nothing will be emerging because this line is used only for sending instructions to the GPS receiver.

When we were trying out the newer GPS modules for the El Cheapo Modules article published in the October 2017 issue (siliconchip.com.au/Article/10820), we found that the newer modules are set to provide the NMEA data stream at 9600 baud rather than the 4800 baud used by the Garmin module in the original GPS Frequency Reference.

So there is a compatibility problem because the program originally written for the PIC16F628A expects to get the data stream at 4800 baud. That could explain your display of all zeros.

One way to check this out would be to connect your GPS module up to a USB port of your PC via a UART-USB bridge module (as shown in Fig.4 of the October 2017 issue on page 39) and use a terminal emulator program like Tera Term to see if the data stream is arriving at 9600 baud.

In fact, shortly after your query arrived we decided to revise the software and now have the HEX code (GPSFrqRfv4.hex, for programming a PIC16F628A) on our online store.

Alternatively, you can order a programmed micro with the revised software. The old version of the software is still available if you end up using a 4800 baud GPS module.

This should solve your problem with using one of the newer V.KEL GPS receiver modules.

It will also allow the GPS Frequency Reference project to be built with the readily available VK2828U7G5LF TTL GPS modules which can also be purchased from our online shop (siliconchip.com.au/Shop/7/3362).

powers LED1 and REG2 that powers LED2), R3 may need to be more than twice the value of R1 or R2 to obtain similar LED brightness.

The photo you sent of the underside of the PCB shows several wire pigtails that are rather long and should be cut shorter to prevent these wires making contact with adjacent parts of the PCB.

We think that's the most likely explanation for why diode D3 burned out. Check also that the capacitors are installed the correct way around on the PCB since if they are backwards, that would also explain it.

Drift in Arduino-based LC Meter measurement

I built the Arduino LC Meter by Jim Rowe from the June 2017 issue (siliconchip.com.au/Article/10676). I initially had a problem where the oscillator frequency was much lower than expected, at around 50kHz rather than 500kHz.

With your help, I tracked the problem down to inductor L1; my parts supplier had given me a 1000µH inductor rather than the 100µH I had asked for.

Now it works well but I have one more question. I tried to calibrate it as described in the magazine in order to optimise the accuracy. However, the lowest reading I got after resetting LC meter several times was 0.02pF and I could not get any better than that. Could you please suggest how to improve or minimise this reading. I tried to make all connection wires as short as possible.

Another issue is the frequency drift. I have very precise capacitors in my lab. One of them is 10nF±0.3%. I managed to calibrate my LC meter with this capacitor and it eventually read 10.015nF. However, one minute later, it measured 10.180nF. Is there any way to minimise this drift?

Otherwise, I am very happy with this LC meter and I appreciate Jim's efforts to share his design with all of us! Thank you, Jim! (Y. A., Kellyville, NSW)

- The minimum reading of 0.02pF could be a result of the drift that you've noticed. The basic design of this meter has been around for many years now and all its incarnations suffer from the same drift issue.

It's because the oscillator is so sensitive to the characteristics of the comparator and the values of the components in the resonant circuit.

As stated in the article, the simplest solution is to leave it on for long enough for the temperature to stabilise before taking any measurements. Or, if you're in a hurry, calibrate the unit immediately before taking a measurement.

The 1nF±1% capacitors we supply for this project in our online shop have a temperature coefficient of around -0.025% per degree. That's pretty good but NP0 ceramics may give better stability. They cost a bit more which is the main reason we decided to supply polypropylene.

Having said that, we suspect the LM311 comparator causes most of the drift, through changes in its input leakage and offset currents, so chang-

ing these capacitors probably won't do much to improve the situation.

It would be possible to re-design the project to at least partially cancel the drift but it would make both the hardware and software more complex. One approach would be to measure the LM311 temperature (eg, with a thermistor) and use a calibration table to apply compensation based on temperature.

The other approach would be to include a second oscillator identical to the one already present but without provision for calibration or connecting external components. Its frequency would also drift with temperature and the second reading could be used to largely cancel drift in the main oscillator.

Both of these approaches would make the project more difficult and expensive to build. Leaving the unit on for a while before making readings so that its temperature stabilises is certainly simpler.

Query about solar charger voltages

I am currently building the Solar MPPT Charger & Lighting Controller, as described in the February and March 2016 magazines (siliconchip.com.au/Series/296). I plan to use it with a Gel-tech SLA battery of 90Ah. I noticed in the article that the unit charges to 14.5V and then sits at 14.5V for one hour before reducing to 13.5V.

The battery manufacturer specifies the charging voltage at 20°C as a maximum of 14.15V and an optimum of 13.85V. The float voltage is 13.55V.

I have been charging the battery with an inbuilt charger in my caravan which sits at 13.8V maximum and I have not had any trouble with it.

In light of the fact that the battery maker is quite insistent that the charging be done by a temperature-compensated regulated charger set to the specified voltage, can the charge controller be altered to charge at 13.85V?

Could the one hour at 14.5V be deleted so as to minimise the time at the high voltage? Is it as critical with a solar panel which may not have the same current capacity as a mains charger? (B. D., Mount Hunter, NSW)

● With the design as it stands, the absorption voltage could be reduced to 14.1V and then 13.2V for the float. That would require a 0.319 multiplier value instead of the 0.3125 multiplier used in the calibration. See Step 5 on page 63 of the March 2016 issue for details on how to set this.

Alternatively, you could opt for a 13.85V absorption voltage and a lower float voltage using a 0.325 multiplier in the calibration. That would result in a float voltage of 13V. Depending on its use, you may find this set up to be satisfactory for the battery.

The absorption stage does continue for one hour but the passage of time is counted only when current flows, so if the solar panel isn't receiving sunlight, the hour period is effectively paused.

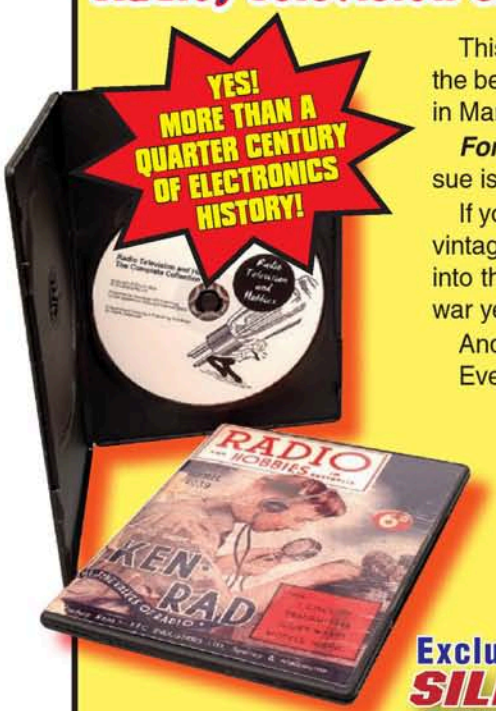
Water Tank Level Indicator needed

I am in need of two of Water Level Indicator PCBs, code 05104021, 80 x 50mm. These are from the project published in the April 2002 issue. How much will they cost with shipping to Saudi Arabia?

● Unfortunately, we do not stock this item.

We published an updated version of this project in the July 2007 issue (siliconchip.com.au/Article/2277). We do not stock the PCB but Everyday Practical Electronics re-published our

Radio, Television & Hobbies: the COMPLETE archive on DVD



This remarkable collection of PDFs ***covers every issue*** of R & H, as it was known from the beginning (April 1939 – price sixpence!) right through to the final edition of R, TV & H in March 1965, before it disappeared forever with the change of name to EA.

For the first time ever, complete and in one handy DVD, every article and every issue is covered.

If you're an old timer (or even young timer!) into vintage radio, it doesn't get much more vintage than this. If you're a student of history, this archive gives an extraordinary insight into the amazing breakthroughs made in radio and electronics technology following the war years.

And speaking of the war years, R & H had some of the best propaganda imaginable!

Even if you're just an electronics dabbler, there's something here to interest you.

- Every issue individually archived, by month and year
- Complete with index for each year
- A must-have for everyone interested in electronics

ONLY $62.00 +$10.00 P&P

Exclusive to: SILICON CHIP

Order now from www.siliconchip.com.au/Shop/3 or call (02) 9939 3295 and quote your credit card number.

article (with permission) in 2009 and produced a PCB which is for sale on their website (PCB product code 701) at: siliconchip.com.au/link/aaif

More recently, we published an Ultrasonic Water Level Gauge design in September 2011 of which Jaycar Electronics sell a kit (KC5503). The article can be previewed at siliconchip.com.au/Article/1150

We also published a PIC-Based Water Tank Level Meter with Telemetry in the November and December 2007 and January 2008 issues. The Jaycar kits for this project have been discontinued but the PCBs (code 04101081/04101082/04111071) are available from EPE (Cat 753/757/758). The articles can be previewed at siliconchip.com.au/Series/46

Finally, we plan to publish an Arduino/ESP8266-based Water Tank Level meter project in the February 2018 issue.

MPPT Controller has no equalisation mode

John Clarke's MPPT Solar Charger project in the March 2012 issue (siliconchip.com.au/Article/749) has a cell equalisation function for lead-acid batteries but the Solar MPPT Charger & Lighting Controller in the February and March 2016 issues (siliconchip.com.au/Series/296) does not.

As kits for the 2012 design are no longer available from Altronics and I am too old to want to roll my own, is there some way to add an equalisation setting to the Solar MPPT Charger & Lighting Controller? (R. P., Swan Bay, NSW)

● The MPPT Charger and Lighting Controller does not include the equalisation feature, mainly because it is not intended to be used with large stationary batteries which benefit most from equalisation.

To incorporate equalisation into the MPPT Charger and Lighting Controller, the software would need to be rewritten and tested and we are not able to do this at the moment.

Equalisation is only required periodically so perhaps you could use a mains-powered charger to do this on occasion (eg, every few months).

Solar panel voltage must match battery for MPPT

Just a quick query on the Solar MPPT Charger & Lighting Controller project from the February and March 2016 issues (siliconchip.com.au/Series/296). It's not clear to me if you can use a 48V solar panel and a 12V battery with this system.

I have a 250W solar panel and would like to use and build the controller to use with a 12V battery system. My panel seems to have an open-circuit voltage of about 45V. (G. P., Narre Warren, Vic)

● The MPPT Charger can't handle a solar panel with a voltage that much higher than the battery. For a 12V battery, you would use a nominal 12V panel. That would have an open circuit voltage of around 21-23V, with maximum power available at around 18V.

The Maximum Power Point Tracking controller would then reduce this to around 12-14.5V, depending on the state of battery charge.

Using a 24V panel (maximum power at around 36V) is not within the scope of the design. That would require conversion from 36V down to 12-14.4V, resulting in very high peak currents and short Mosfet on-times.

The MPPT converter does not have the switching range for proper conversion or tracking under these conditions. Based on the open circuit voltage of your panel at 45V, it is probably meant for use with a 24V battery.

MPPT Charger battery questions

I have questions regarding two of your MPPT charger projects, the Solar MPPT Charger and Lighting Controller of February/March 2016 (siliconchip.com.au/Series/29) and the Solar Powered Lighting System of May/June 2010 (siliconchip.com.au/Series/9).

I have built the 2016 project but was wondering exactly why a battery of over 80Ah is recommended. Unless I missed something, the construction notes supplied with the Altronics kit do not say why a minimum battery size is specified.

I want to use it in a remote application with a 12V, 7Ah battery and a pair of 10W solar panels in parallel. I've experimented on the bench with a 40W workshop panel and both a 12V 7Ah SLA battery and a 12V 7Ah Li-Ion battery in the same form factor and preliminary observation suggests that the smaller batteries charge quite well.

The charger also does a fine job of charging my 120Ah workshop/

Problem with water level sensor

I have a problem with a water level kit. I have a bore with a bore pump which is driven by a diesel engine. Due to the dry weather, I am concerned it may run dry whilst pumping and damage the mono pump.

I purchased a water level kit from Vidcom, Toowoomba and also a 12V DC relay switch, to switch off the diesel engine if the bore water level drops below a critical depth.

When I assembled the two in my workshop, they both worked perfectly but when I attached them to my diesel motor and bore pump and to water sensors which are connected to a 30m length of cable (the depth of that bore) nothing happened.

On reading the print description afterwards, that particular water level kit can only handle a half-metre cable to the sensor and not my 30m long cable.

Would you please advise if I can modify that water level kit (diagram of the kit attached). Or do you have any suggestions? Any help would be appreciated.

● The water level kit you are referring to is not a SILICON CHIP design.

However, you could possibly get the water level sensor to work if you placed its PCB close to the sensor probes so that these leads are kept short, with the longer wires from the PCB (supply and signal wire) up from the bore water level to ground level.

The PCB would need to be protected by placing it in a waterproof box with waterproof cable glands for the wires or suitably sealed with Silicone or potting compound.

Note, we are planning on publishing a Water Level Meter project next month which uses a pressure sensor that should work with a 30m cable (although it's only capable of measuring water up to 6m deep).

It would need some slight software modifications to suit your application.

Can't calibrate touchscreens on Micromite Plus Explore 100

I recently purchased 8-inch and 5-inch EastRising LCD panels for my two Explore 100 boards (September-October 2016; siliconchip.com.au/Series/304).

I also bought a 5-inch LCD panel recommended in the July issue on page 103. I purchased the Explore 100 boards from Rictech in New Zealand (www.micromite.org).

I cannot get the touchscreen calibration to run successfully on any of the panels on either Micromite board. Also, the 5-inch EastRising panel has the red and blue colours reversed. For example, the command below produces blue:

```
CLS
RGB(RED)
```

When "GUI Calibrate" is run the following occurs:

1) A target appears in top left-hand corner (as it should).
2) On pressing this target, it disappears and a target appears in the top right-hand corner (as it should).
3) On pressing the target, it disappears and the error message "touch hardware failure" appears.

I believe that I have wired everything correctly and set the options correctly.

I have wired the LCD panels up to the Explore 100 boards (rather than plugging them in) as my initial attempt was with the East-Rising boards which use a different connector pinout.

The Explore 100 itself appears to function fine, it is only the touch facility and the colour reversal on the 5-inch EastRising board which are problems.

Any suggestions most welcome. (D. W., Kiama, NSW)

● Geoff Graham responds: the "Touch hardware failure" error is generated when the touch controller chip reports that the first calibration point (top left) is the same as the top right calibration point (within 16 pixels).

The controller chip does not give a reliable indication that it is working correctly, so this is the only way that the firmware can detect a problem.

This could be caused by bad wiring but I am prepared to bet that it is caused by something on the SPI bus (probably the SD card) responding at the same time as the touch controller chip because its CS line is left floating.

To avoid this, your reader should remove the SD card until he has configured it, then (when configured), MMBasic will know to drive the SD card's CS line to prevent it from floating.

The manual mentions this many times but it is easy to forget and has tripped up more than a few constructors (including me).

Unfortunately, EastRising do not like adhering to any standards so I am not surprised that they decided to swap two of the colour signals. In fact, I would be amazed if that was the only thing they changed so your reader should watch out for other issues that may be lurking in the background.

The only fix for this is to avoid EastRising products altogether or swap signals in his adapter cable or cut and re-route tracks on the PCB.

emergency blackout AGM battery, which is what I built it for in the first place.

I have read the article for the 2010 project which looks very similar in design, only with smaller power semiconductors and the problem with that one is that the article specifies a battery smaller than the 7Ah ones I have in mind.

So will either design be suitable for my application? (P. H., Mackay, Qld)

● The rated battery capacity for each project was based on the charger being able to charge the battery in one day, assuming it is initially discharged.

The Solar MPPT Charger and Lighting Controller from February/March 2016 recommends an 80Ah battery because this suits the 120W solar panel for charging in one day.

If you use a 20W solar panel (2 x 10W) then the smaller 7Ah capacity battery should be fine. The only thing to realise is that the design was optimised for higher wattage, so the MPPT charging will be less efficient.

The Solar Powered Lighting System of May/June 2010 was designed for 5W solar panels and so we recommended a 3.3Ah battery, which can then be charged in a single day, so that the battery is ready to power the lights overnight.

A 7Ah battery will take over 16 hours to charge and that is too long for winter days which probably means at least two days of charging. If you are not concerned about charging time, then it can be used.

Discontinued dual-gate Mosfet substitute

You stock the BSS83 Mosfets for the Wideband Differential Oscilloscope Probe project (siliconchip.com.au/Article/7995) in your online shop (siliconchip.com.au/Shop/7/3108) and note:

"These low-capacitance dual-gate Mosfets are used as the input buffers in the Wideband Active Differential Oscilloscope Probe. Unfortunately, they are no longer being manufactured and there is no direct replacement so we are making them available for people who wish to build this project."

Are the SST213 or SST215 from Siliconix/Vishay or Calogic suitable as drop-in replacements for the BSS83? They are not widely stocked but can be sourced on eBay. (P. B., Beacon Hill, NSW)

● The SST213/215 appear to be a reasonable substitute for the BSS83. The package and pinout appears to be identical and the specifications are similar.

Our only concern is that the various capacitances of the SST213/215 are higher than the BSS83 and the turn-off time is slower. This could reduce the bandwidth slightly. But the differences are not huge so we would expect the Active Differential Probe to work OK with these alternatives.

Can Majestic woofer be substituted?

I am thinking of building the Majestic speakers which were published in the June 2014 issue (siliconchip.com.au/Series/275). Would one of the

woofers at the following link be a suitable substitute for the eTone woofer that was specified (siliconchip.com.au/link/aai2)? (T. V., Auckland, NZ)

● Those woofers are far too inefficient. The three different versions you've nominated are rated at 90dB, 91dB and 92dB per watt at one metre. The eTone woofer is rated at 97.2dB/W@1m.

Many people have written in to tell us that despite what others have said, eTone is still in operation and the specified woofer is still available.

We suggest you contact them and try to get the originally specified units, which are excellent.

Faulty component in 433MHz Remote Switch

I have a problem with the 433MHz UHF Remote Switch kit which I bought from Jaycar, Cat KC5473. It is based on your article in the January 2009 issue (siliconchip.com.au/Article/1284).

It is intermittently not operating. Maybe about 1 in 15 operations do not work.

There is not much discernible pattern to it except that I have noticed that sometimes two consecutive operations don't work. The important points to note are:

1) The soldering quality is good. I'm an electronics tech and know how to solder, but I checked it anyway!
2) I checked the component placement and found no problems.
3) I have replaced both the TX and RX modules. No effect on the fault.
4) I added decoupling to the identity input to the transmitter IC in case RF from the module was intermittently changing the identity voltage but it made no difference. Changing the identity makes no difference either.
5) I am triggering it with a pushbutton switch (S1) but it is mounted externally on the case. This switch is not the problem as it happened with the original PCB-mounted switch which prompted me to use an external switch instead.
6) This issue is not related to where the unit is operated. The fault occurs at home, at work and wherever it is being used.
7) The Transmit LED on the transmitter always flashes in exactly the same manner whether that particular operation works or not.
8) In my setting up and operating the unit in its final home, it seems to have a much shorter range than the claimed 200 metres. I'm getting reasonably reliable range of 10m but anything more and it struggles. I'm using plastic boxes at both ends.

It is starting to look to me as if one of the PICs is the problem, either hardware or the code has a bug.

It is important because it is needed for a dance group which meets in a community centre which is locked for security reasons and a permanently wired bell is not possible.

If the bell does not work then somebody is stuck outside waiting without knowing that when they pressed the bell nothing happened and nobody inside knows they are there.

We have tried using normal commercially available units but their nice melodious tones can't be heard over the music.

I have built the output of this unit to produce a very harsh noise using two piezo buzzers, supplemented this with two super bright LED's.

I realise that this is an older kit, but it is still available. Hopefully you have somebody there who can shed some light on this for me. (J. B., via email)

● We suspect that one of the identity pots has an open-circuit wiper. Check VR1 on both the transmitter and receiver at TP1 and check that the voltage varies smoothly with adjustment. To reduce the likelihood of problems with this, set both VR1 trimpots to either 0V or 5V.

For best range, make sure the antennas are 170mm long.

Troubleshooting 433MHz Remote Switch

I just bought a kit from Jaycar but I am new to building kits. I am a beginner with a particular use for the 433MHz UHF Remote Switch project from the January 2009 magazine article (siliconchip.com.au/Article/1284).

I have finished all the soldering and fitting the completed units into a couple of boxes with new 9V batteries but the green LED doesn't light up when I press the button on the transmitter.

I did the required tests and got 5V across pins 1 and 8 before fitting the chips. I'm not sure what to do now.

I re-soldered a few joints that looked iffy and am still getting 5V as before but no green light. Can you point me in the right direction for testing or whatever I need to do?

I am hoping to use it for my new emergency generator which I had fitted with a two-wire signal terminal to switch it on and off. I am hoping the receiver can somehow create a short-circuit to turn it on and then a disconnect to turn it off. (K. B., Black Mountain, Qld)

● If the LED on the transmitter does not light when S1 is pressed, check that 5V power is at IC1 (between pins 1 and 8).

Also check that the LED is oriented correctly and that you are using the correct transistors in the Q1, Q2 and Q3 positions. Q1 is a BC327 while Q2 and Q3 are BC337 types.

If the LED on the transmitter does light but the receiver LED does not, check you have set the same identity on both the transmitter and receiver. Also that pins 1 and 8 of IC1 on the receiver have 5V.

The receiver output is an open collector where you can connect a 12V relay coil, allowing the relay contacts to switch on your emergency generator. See end of page 88 of the January 2009 issue for instructions on how to use it with a relay.

Amplifier design for 2-ohm subwoofers

Will SILICON CHIP ever consider designing a high-power 2Ω stable amplifier for subwoofer purposes? 2Ω loads are very common now for subwoofers.

Alternatively, can I use the SILICON CHIP CLASSiC-D modules (www.siliconchip.com.au/Series/17) on 2Ω loads with reduced supply rails? (J. A., St Clair, NSW)

● It is true that most subwoofer systems in cars are based on 2Ω drivers but as far as we are aware, 2Ω drivers are not commonly used in domestic subwoofer systems.

That being the case, there is little reason for producing a high-powered amplifier for 2Ω loudspeakers. Moreover, high sound quality is easier to obtain with drivers which have a nominal impedance of 4 or 8 ohms.

However, you can use the CLASSiC-D amplifier to drive a 2Ω load but the supply rails will need to be ±25V. Table 1 in part 2 (December 2012) shows the required component changes. SC

SILICON CHIP .com.au/shop ONLINESHOP

Looking for a specialised component to build that latest and greatest *Silicon Chip* project? Maybe it's the PCB you're after? Or a pre-programmed micro? Or some other hard-to-get "bit"? The chances are they are available direct from the *Silicon Chip* ONLINESHOP.

As a service to readers, *Silicon Chip* has established the ONLINESHOP. No, we're not going into opposition with your normal suppliers – this is a direct response to requests from readers who have found difficulty in obtaining specialised parts such as PCBs & micros.

- PCBs are normally IN STOCK and ready for despatch when that month's magazine goes on sale (you don't have to wait for them to be made!).
- Even if stock runs out (eg, for high demand), in most cases there will be no longer than a two-week wait.
- One low p&p charge: $10 per order, regardless of how many boards or micros you order! (Australia only; overseas clients – email us for a postage quote).
- Our PCBs are beautifully made, very high quality fibreglass boards with pre-tinned tracks, silk screen overlays and where applicable, solder masks.
- Best of all, those boards with fancy cut-outs or edges are already cut out to the *SILICON CHIP* specifications – no messy blade work required!

HERE'S HOW TO ORDER:

VISA MasterCard PayPal

All prices are in AUSTRALIAN DOLLARS ($AU)

✔ **Via the INTERNET** (24 hours, 7 days): Log on to our secure website – siliconchip.com.au, click on "SHOP" and follow the links

✔ **Via EMAIL** (24 hours, 7 days): email silicon@siliconchip.com.au – Clearly tell us what you want and include your contact and credit card details

✔ **Via MAIL** (24 hours, 7 days): PO Box 139, Collaroy NSW 2097. Clearly tell us what you want and include your contact and credit card details

✔ **Via PHONE** (9am-5pm EADST, Mon-Fri): Call (02) 9939 3295 (INT 612 9939 3295) – have your order ready, including contact and credit card details!

YES! You can also order or renew your SILICON CHIP subscription via any of these methods as well!

PRE-PROGRAMMED MICROS

Price for any of these micros is just $15.00 each + $10 p&p per order#

As a service to readers, *Silicon Chip OnLineShop* stocks microcontrollers and microprocessors *used in new projects* (from 2012 on) and some selected older projects – pre-programmed and ready to fly!

Some micros from copyrighted and/or contributed projects may not be available.

PIC12F675-I/P	UHF Remote Switch (Jan09), Ultrasonic Cleaner (Aug10), Ultrasonic Anti-fouling (Sep10), Cricket/Frog (Jun12), Do Not Disturb (May13) IR-to-UHF Converter (Jul13), UHF-to-IR Converter (Jul13) PC Birdies *2 chips – $15 pair* (Aug13), Driveway Monitor Receiver (July15) Hotel Safe Alarm (Jun16), 50A Battery Charger Controller (Nov16) Kelvin the Cricket (Oct17)
PIC12F675-E/P	Courtesy LED Light Delay for Cars (Oct14), Fan Speed Controller (Jan18)
PIC16F1455-I/P	Microbridge (May17)
PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul12)
PIC16F88-E/P	Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13), Auto Headlight Controller (Oct13), 10A 230V Motor Speed Controller (Feb14) Automotive Sensor Modifier (Dec16)
PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11) Quizzical (Oct11), Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jun13), Revised 10-Channel Remote Control Receiver (Jul13) Nicad/NiMH Burp Charger (Mar14), Remote Mains Timer (Nov14) Driveway Monitor Transmitter (July15), Fingerprint Scanner (Nov15) MPPT Lighting Charge Controller (Feb16), 50/60Hz Turntable Driver (May16) Cyclic Pump Timer (Sep16), 60V 40A DC Motor Speed Controller (Jan17) Pool Lap Counter (Mar17), Rapidbrake (Jul17)
PIC16LF88-I/P	Garbage Reminder (Jan13), Bellbird (Dec13), GPS Analog Clock Driver (Feb17)
PIC16LF88-I/SO	LED Ladybird (Apr13)
PIC16LF1709-I/SO	Battery Cell Balancer (Mar16)
PIC16F877A-I/P	6-Digit GPS Clock (May-Jun09), Lab Digital Pot (Jul10), Semtest (Feb-May12)
PIC16F2550-I/SP	Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10)
PIC18F4550-I/P	GPS Car Computer (Jan10), GPS Boat Computer (Oct10)
PIC32MX795F512H-80I/PT	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12) Touchscreen Audio Recorder (Jun/Jul 14)
PIC32MX170F256B-50I/SP	Micromite Mk2 (Jan15) – *also includes* ***FREE*** *47µF tantalum capacitor* Micromite LCD BackPack [either version] (Feb16), GPS Boat Computer (Apr16) Micromite Super Clock (Jul16), Touchscreen Voltage/Current Ref (Oct-Dec16) Micromite LCD BackPack V2 (May17), Deluxe eFuse (Aug17) Micromite DDS for IF Alignment (Sept17)
PIC32MX170F256B-I/SP	Low Frequency Distortion Analyser (Apr15)
PIC32MX170F256D-501P/T	44-pin Micromite Mk2 (Now with Mk2 Firmware at no extra cost)
PIC32MX250F128B-I/SP	GPS Tracker (Nov13), Micromite ASCII Video Terminal (Jul14)
PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb 14) Digital Effects Unit (Oct14)
PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SportSync (May11), Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)
dsPIC33FJ64MC802-E/P	Induction Motor Speed Controller (revised) (Aug13)
dsPIC33FJ128GP306-I/PT	CLASSiC DAC (Feb-May 13)
ATTiny861	Thermometer/Thermostat (Mar10), Rudder Position Indicator (Jul11)

When ordering, be sure to nominate BOTH the micro required AND the project for which it must be programmed.

SPECIALISED COMPONENTS, HARD-TO-GET BITS, ETC

P&P – $10 Per order#

NEW THIS MONTH:

EL CHEAPO MODULES *(JAN 18)*
NRF24L01+PA+NA transceiver with SNA connector and antenna — $12.50

ALTIMETER/WEATHER STATION *(DEC 17)*
Micromite 2.8-inch LCD BackPack kit programmed for the Altimeter project — $65.00
GY-68 barometric pressure and temperature sensor module (with BMP180) — $5.00
DHT22 temperature and humidity sensor module — $7.50

PARTS FOR THE 6GHz+ TOUCHSCREEN FREQUENCY COUNTER *(OCT 17)*
Explore 100 kit (Cat SC3834; no LCD included) — $69.90
one ERA-2SM+ & one ADCH-80A+ (Cat SC1167; two packs required) — $15.00/pack

3-WAY ADJUSTABLE ACTIVE CROSSOVER *(SEPT 17)*
set of laser-cut black acrylic case pieces — $10.00

LOGGING DATA TO THE 'NET USING ARDUINO *(SEPT 17)*
WeMos D1 R2 board — $12.50

DELUXE EFUSE PARTS *(AUG 17)*
IPP80P03P4L04 P-channel mosfets — $4.00 ea
BUK7909-75AIE 75V 120A N-channel SenseFet — $7.50 ea
LT1490ACN8 dual op amp — $7.50 ea

ARDUINO MUSIC PLAYER/RECORDER *(JUL 17)*
Geeetech Arduino MP3 shield — $20.00

ARDUINO LC METER *(JUN 17)*
1nF 1% MKP capacitor, 5mm lead spacing — $2.50

MICROBRIDGE *(MAY 17)*
PCB plus all on-board parts including programmed microcontroller (SMD ceramics for 10µF) — $20.00

MICROMITE LCD BACKPACK V2 – COMPLETE KIT *(MAY 17)*
includes PCB, programmed micro, touchscreen LCD, laser-cut UB3 lid, mounting hardware, SMD Mosfets for PWM backlight control and all other on-board parts — $70.00

EFUSE *(APR 17)*
two NIS5512 ICs plus one SUP53P06 — $22.50

POOL LAP COUNTER *(MAR 17)*
two 70mm 7-segment high brightness blue displays plus logic-level Mosfet — $17.50
laser-cut blue tinted lid, 152 x 90 x 3mm — $7.50

STATIONMASTER *(MAR 17)*
Hard to get parts: DRV8871 IC, SMD 1µF capacitor and 100kW potentiometer with detent — $12.50

ULTRA LOW VOLTAGE LED FLASHER *(FEB 17)*
kit including PCB and all SMD parts, LDR and blue LED — $12.50

SC200 AMPLIFIER MODULE *(JAN 17)* — $35.00
hard-to-get parts: Q8-Q16, D2-D4, 150pF/250V capacitor and five SMD resistors

60V 40A DC MOTOR SPEED CONTROLLER *(JAN 17)* — $35.00
hard-to-get parts: IC2, Q1, Q2 and D1

VARIOUS MODULES
AD9833 DDS module (with gain control) (for Micromite DDS, APR17) — $25.00
AD9833 DDS module (no gain control) (El Cheapo Modules, Part 6, APR17) — $15.00
CP2102 USB-UART bridge — $5.00
microSD card adaptor (El Cheapo Modules, Part 3, JAN17) — $2.50
DS3231 real-time clock with mounting spacers and screws (El Cheapo, Part 1, OCT16) — $5.00

TOUCHSCREEN VOLTAGE/CURRENT REFERENCE *(DEC 16)*
MICROMITE LCD BACKPACK KIT (programmed to suit) PLUS UB1 Lid — $70.00
LASER-CUT MATTE BLACK LID (to suit UB1 Jiffy Box) — $10.00
SHORT FORM KIT with main PCB plus onboard parts (not including BackPack module, jiffy box, power supply or wires/cables) — $99.00

MICROMITE PLUS EXPLORE 100 ***COMPLETE KIT (no LCD panel)*** *(SEP 16)* — $69.90
(includes PCB, programmed micro and the hard-to-get bits including female headers, USB and microSD sockets, crystal, etc but does not include the LCD panel)

THESE ARE ONLY THE MOST RECENT MICROS AND SPECIALISED COMPONENTS. FOR THE FULL LIST, SEE www.siliconchip.com.au/shop

*All items subect to availability. Prices valid for month of magazine issue only. All prices in Australian dollars and included GST where applicable. **# P&P prices are within Australia. O'seas? Please email for a quote**

01/18

PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB only – *not a full kit*. If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP ONLINESHOP has boards going back to 2001 and beyond. For a complete list of available PCBs, back issues, etc, go to *siliconchip.com.au/shop* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103131	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSiC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSiC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSiC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHz UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L'IL PULSER MKII TRAIN CONTROLLER	JULY 2013	09107131	$15.00
L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SiDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SiDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp [Sept11])	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSiC-D Amp board and CLASSiC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
Li'l Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	-	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	1510815	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50
6GHz+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017		$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
DELUXE EFUSE	AUG 2017	18106171	$15.00
DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00
MAINS SUPPLY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$25.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00
6GHz+ FREQUENCY COUNTER CASE PIECES (SET)	DEC 2017		$15.00
SUPER-7 SUPERHET AM RADIO PCB	DEC 2017	06111171	$25.00
SUPER-7 SUPERHET AM RADIO CASE PIECES	DEC 2017		$20.00
NEW THIS MONTH			
THEREMIN	JAN 2018	23112171	$12.50
PROPORTIONAL FAN SPEED CONTROLLER	JAN 2018	05111171	$2.50

LOOKING FOR TECHNICAL BOOKS? YOU'LL FIND THE COMPLETE LISTING OF ALL BOOKS AVAILABLE IN THE SILKS & DVDs" PAGES AT SILICONCHIP.COM.AU/SHOP

Subscribe to SILICON CHIP and you'll not only save money but we GUARANTEE you'll get your copy!

When you subscribe to SILICON CHIP (printed edition) in Australia, we GUARANTEE that you will never miss an issue.

Subscription copies are despatched in bulk at the beginning of the on-sale week (due on sale the last THURSDAY of the previous month). It is unusual for copies to go astray in the post but when we're mailing many thousands of copies, it is inevitable that Murphy may strike once or twice (and occasionally three and four times!).

So we make this promise to you: if you haven't received your SILICON CHIP (anywhere in Australia) by the middle of the month of issue (ie, issue datelined "June" by, say, 15th June), send us an email and we'll post you a replacment copy in our next mailing (we mail out twice each week on Tuesday and Friday).

Send your email to: missing_copy@siliconchip.com.au

- ✔ Remember, it's cheaper to subscribe anyway . . . do the maths and see the saving!
- ✔ Remember, we pick up the postage charge – so you $ave even more!
- ✔ Remember, you don't have to remember! It's there every month in your letter box!
- ✔ Remember, your newsagent might have sold out – and you'll miss out!
- ✔ Remember, there's also an on-line version you can subscribe to if you're travelling.

Convinced? We hope so. And we make it particularly easy to take out a subscription - for a trial 6-month, a standard 12-month or even a giant 24-month sub with extra savings.

Here's how: simply go to our website (siliconchip.com.au/subs) – enter your details and pay via Paypal or EFT/Direct Deposit. You can order by mail with a cheque/money order, or we can accept either Visa or Mastercard (sorry, no Amex nor Diners').

If mailing, send to SILICON CHIP, PO Box 139, Collaroy NSW 2097, with your full details (don't forget your address and all credit card details including expiry!).

We're waiting to welcome you into the SILICON CHIP subscriber family!

MARKET CENTRE

Cash in your surplus gear. Advertise it here in SILICON CHIP

FOR SALE

tronixlabs.com.au – Australia's best value for hobbyist and enthusiast electronics from adafruit, DFRobot, Freetronics, Raspberry Pi, Genuino and more, with same-day shipping.

PCBs MADE, ONE OR MANY. Any format, hobbyists welcome. Sesame Electronics Phone 0434 781 191.
nev-sesame@outlook.com
www.sesame.com.au

LEDs, BRAND NAME and generic LEDs. Heatsinks, fans, LED drivers, power supplies, LED ribbon, kits, components, hardware, EL wire.
www.ledsales.com.au

PCB MANUFACTURE: single to multilayer. Bare board tested. One-offs to any quantity. 48 hour service. Artwork design. Excellent prices. Check out our specials: www.ldelectronics.com.au

Attention all AUDIOPHILES!

Described in SILICON CHIP June 2017

Does your audio system sound exactly the way you want it? Room deficiencies or even system quirks ruining your listening? Fix sound problems and make listening the pleasure it should be with this magnificent

10-Octave Graphic Equaliser

– the very latest in a long line of high-spec audio gear from the **SILICON CHIP** laboratory.

View online at siliconchip.com.au/Article/10674

PCB & hard-to-get bits available from SILICON CHIP online shop

ORDER NOW AT
www.siliconchip.com.au/shop

ARDUINO

Described in SILICON CHIP June 2017

Arduino-based Digital LC Meter

Gives you an accurate digital readout of inductance and capacitance, even in circuit. It measures inductance from 10nH to 100mH(+) and capacitance from 0.1pF to 2.7µF (non-polarised), with five digit resolution and automatic range selection.

View online at siliconchip.com.au/Article/10676

Lid & hard-to-get bits available from SILICON CHIP online shop

ORDER NOW AT
www.siliconchip.com.au/shop

KIT ASSEMBLY & REPAIR

DAVE THOMPSON (the Serviceman from SILICON CHIP) is available to help you with kit assembly, project troubleshooting, general electronics and custom design work. No job too small. Based in Christchurch, NZ but service available Australia/NZ wide.
Email dave@davethompson.co.nz

VINTAGE RADIO REPAIRS: electrical mechanical fitter with 36 years experience and extensive knowledge of valve and transistor radios. Professional and reliable repairs. All workmanship guaranteed. $17 inspection fee plus charges for parts and labour as required. Labour fees $38 p/h. Pensioner discounts available on application.
Contact Alan on 0425 122 415 or email bigalradioshack@gmail.com

KEITH RIPPON KIT ASSEMBLY & REPAIR:
* Australia & New Zealand;
* Small production runs.

Phone Keith 0409 662 794.
keith.rippon@gmail.com

ADVERTISING IN MARKET CENTRE

Classified Ad Rates: $32.00 for up to 20 words (punctuation not charged) plus $1.20 for each additional word. Display ads in Market Centre (minimum 2cm deep, maximum 10cm deep): $82.50 per column centimetre per insertion. All prices include GST. Closing date: 5 weeks prior to month of sale. To book, email the text to silicon@siliconchip.com.au and include your name, address & credit card details, or phone Glyn (02) 9939 3295 or 0431 792 293.

WARNING!

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine.

Devices or circuits described in SILICON CHIP may be covered by patents. SILICON CHIP disclaims any liability for the infringement of such patents by the manufacturing or selling of any such equipment. SILICON CHIP also disclaims any liability for projects which are used in such a way as to infringe relevant government regulations and by-laws.

Advertisers are warned that they are responsible for the content of all advertisements and that they must conform to the Competition & Consumer Act 2010 or as subsequently amended and to any governmental regulations which are applicable.

Coming up in Silicon Chip

Making Power from Rubbish
Australia is having increasing difficulty finding somewhere to dump our rubbish and with the shutdown of large power stations, we're also facing an electricity shortage. Why don't we kill two birds with one stone, by burning waste to generate electricity?

Navman Drive Duo review
This combined dashcam and satellite navigation unit combines one of the best dash cameras we've seen with an advanced navigation system including lane guidance, speed limit warnings and a suite of assisted driving technologies. Leo Simpson takes it on a comprehensive road test.

RCWL-0516 motion and CT0007MS soil moisture sensors
Jim Rowe describes the operation of these two different types of sensors from Elecrow. The RCWL-0516 is a microwave radar motion sensor while the CT-0007MS senses soil moisture content and both can be easily hooked up to an Arduino or Micromite.

WiFi Water Tank Level Meter
This project uses an ESP8266-based Arduino and a pressure transducer to log a water level over WiFi to the cloud. It can be solar powered and also acts as a simple weather station.

10-LED Bar/Dot Graph
This is a great project for beginners since it's easy to put together, useful for a number of tasks and you can understand how it works. Use it to display a battery voltage level, audio sound level, RF signal level or just about any other task where you need to show a voltage range.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The February 2018 issue is due on sale in newsagents by Thursday, January 25th. Expect postal delivery of subscription copies in Australia between January 23rd and February 9th.

Advertising Index

Altronics 74-77
Dave Thompson 103
Digi-Key Electronics 3
Freetronics 7
Hare & Forbes ..... OBC
Jaycar IFC,49-56
Keith Rippon Kit Assembly 103
Keysight Technologies 9
KitStop 12
LD Electronics 103
LEACH Co Ltd 5
LEDsales 103
Microchip Technology ..... IBC
Ocean Controls 11
PCBcart 35
Sesame Electronics 103
SC Online Shop 100-101
SC Radio, TV & Hobbies DVD .. 96
Silicon Chip Binders 93
Silicon Chip Subscriptions 102
The Loudspeaker Kit.com 60
Tronixlabs 103
Vintage Radio Repairs 103
Wagner Electronics 10

Notes & Errata

GPS-based Frequency Reference, March 2007: A newer version of the software (v4) is now available on the online shop. This newer version accepts an NMEA data stream at 9600 baud, to suit most recent GPS receiver modules.

VS1053 Arduino Music Player, July 2017: The software has been updated to fix the following issues:
(1) pressing any of the bottom row of keys on the keypad during playback would cause the player to lock up. This was due to that pin being connected to D10 (SS), which was in use by the SPI module. Pin D0 (RX), the only free pin, is now used instead;
(2) recording drop-outs have been solved by writing data to the SD card in larger blocks (ie, writing less frequently);
(3) the player would lock up if certain file types were played back after recording. This was due to the correct plugin not being reloaded after recording, which has been fixed;
(4) a few small additional improvements were made.

Touchscreen 6GHz+ Frequency Counter, October-December 2017: REG1 and REG3 are TPS73701 regulators, as shown in the parts list on page 33 of the October 2017 issue, not TPS73700 as shown in the circuit diagram (Fig.2) on page 30 of that same issue.

Kelvin the Cricket, October 2017: the parts list on page 46 gives the incorrect Jaycar catalog code for the piezo buzzer. It should be AB-3440.

Vintage Radio, November 2017: in Figs.1 & 2, coupling capacitor C4 has been drawn connected to the wrong side of L2. It is connected to the plate of V1, not the junction of L2 and L3.

The User Interface is the Product

Give It a New Touch

An innovative product needs a modern user interface to meet customer expectations. An outdated user interface puts revenue at risk. The CAP1xxx, MTCH10x and AT42QTxxxx families of turnkey touch controllers provide robust and water-tolerant touch sensing. This technology is based on Microchip's decades of experience in touch.

User interfaces with push buttons have several moving parts, which significantly decrease reliability, add complexity and increase tooling costs. Microchip's touch solutions allow you to create a high-impact user interface at a lower total system cost.

MTCH108 Evaluation Board (DM160229)

CAP1188 Evaluation Board (DM16022)

CAP1928 Evaluation Board (DM160223)

Contact Information
Microchip Technology Australia
Email: aust_nz.inquiry@microchip.com
Phone: +61 (2) 9868-6733

www.microchip.com/touch

microchip DIRECT
www.microchipdirect.com

MICROCHIP

The Microchip name and logo, the Microchip logo and PIC are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners. © 2018 Microchip Technology Inc. All rights reserved.

HARE&FORBES MACHINERYHOUSE

"Setting the standard for Quality & Value"

A family owned Australian business
Established 1930

THE INDUSTRY'S CHOICE!

CNC Machinery | Metal Working | Sheet Metal Fabrication | Wood Working | Workshop & Automotive | Lifting Handling | Cutting Tools | Machine Tool Accessories | Measuring Equipment

HSS Industrial Centre Drill Set

- 5 piece set
- No. 1, 2, 3, 4, 5
- HSS M2 grade
- Industrial quality

$40 ~~$47.30~~ (D508)

Metric Precision HSS Jobber Drill Set

- 25 piece set
- Precision ground flutes
- HSS M2 bright finish
- Range: 1~13mm
- 0.5mm increments

$79 ~~$99~~ (D1272)

Imperial Precision HSS Jobber Drill Set

- 29 piece set
- Precision ground flutes
- HSS M2 bright finish
- Range: 1/16 ~ 1/2"
- 1/64" increments

$88 ~~$104.50~~ (D1282)

Metric Precision HSS Jobber Drill Set

- 51 piece set
- Precision ground flutes
- 1-6mm in 0.1mm increments
- HSS M2 grade

$99 ~~$126.50~~ (D1285)

Metric Carbide Tipped Hole Saw Set

- 8 piece set
- 16, 20, 22, 25, 28, 30, 32, 35mm
- Carbide teeth
- Ø10mm shank

$84 ~~$99~~ (D108)

HSS Sheet Metal Step Drill Set

- 3 piece set
- For drilling thin material
- HSS M2 grade
- 4-12mm x 1mm steps
- 6-20mm x 2mm steps
- 6-30mm x 2mm steps

$66 ~~$82.50~~ (D1071)

HSS Countersink Set

- 4 piece set
- HSS M2 grade
- 45° angle
- Ø2 ~ Ø5mm
- Ø5 ~ Ø10mm
- Ø10 ~ Ø15mm
- Ø15 ~ Ø20mm

$55 ~~$71.50~~ (D1051)

Metric HSS Combination Tap & Drill Set

- 7 piece set
- Designed for up to 3.2mm sheet metal
- HSS M2 grade
- M3, M4, M5, M6, M8, M10
- Includes hex snap-on drive

$56 ~~$66.55~~ (T0191)

HSS Countersink Set

- 6 piece set
- HSS M2 grade
- 45° angle
- Ø1.5 ~ Ø6.3mm
- Ø6.3 ~ Ø8.3mm
- Ø8.3 ~ Ø10.4mm
- Ø10.4 ~ Ø12.4mm
- Ø12.4 ~ Ø16.5mm
- Ø16.5 ~ Ø20.5mm

$66 ~~$82.50~~ (D1061)

Metric HSS Hole Saw Set

- 11 piece set
- M42 Bi-Metal high speed steel
- 19, 22, 25, 32, 35, 38, 44, 51, 57, 64, 76mm
- Includes 3/8" & 1/2" arbor shank & pilot drill

$89 ~~$110~~ (D102)

EF-5S - Engineers File Set

- 200mm hardened and tempered files
- Second cut: Flat, 1/2 Round, Round, Square, Triangular
- Includes carry case

$29 ~~$42.35~~ (F100)

HS-2S - Throatless Hand Lever Shear

- 1.2mm mild steel capacity
- Cast steel construction
- Tool steel quality blades
- Gear drive shearing action

$209 ~~$253~~ (S184)

DB-180 - Digital Bevel Box

- 180° range
- Auto shut off
- Magnetic base
- 0.1° resolution

$59 ~~$78.65~~ (M977)

Digital Caliper

- 150mm / 6"
- Metric, inch & fraction
- 4-way measuring
- Includes battery

$29 ~~$38.50~~ (M738)

Alloy Steel Tap & Die Set

- 32 piece set
- M3 ~ M12 alloy steel
- Includes button die holder wrench, tap wrench, screw pitch gauge, screwdriver

$60 ~~$71.50~~ (T012)

Alloy Steel Tap & Die Sets

- 45 piece set
- Metric or Imperial fine & coarse set
- M6 ~ M24 alloy steel (T014)
- 1/4" ~ 1" alloy steel (T015)
- Includes die holder & 2 x tap wrenches

Metric **$153** ~~$180.40~~ (T014)

Imperial **$153** ~~$180.40~~ (T015)

HAPPY NEW YEAR DEALS IN STORE & ONLINE

- JAMES
Staff Member

TCS-3 - Mobile Tool Cabinet Seat

- 3 x drawers with ball bearing slides
- 420 x 235mm padded seat
- 2 x magnetic side trays
- 406mm seat height
- 360° swivel wheels

$75 ~~$93.50~~ (A001)

BD-325 - Bench Drill

- 16mm drill capacity
- 2MT spindle
- 12 spindle speeds
- Swivel & tilt table
- 1hp, 240V motor

$289 ~~$319~~ (D590)

VIPER 150 - Multi-Function Inverter Welder-MIG-MMA

- 30 - 150 Amps
- 240V - 10amp
- Gas / gasless
- 15% @ 150A duty cycle

$440 ~~$495~~ (W245)

UNIQUE PROMO CODE

SCJAN8

ONLINE OR INSTORE!

VIEW AND PURCHASE THESE ITEMS ONLINE AT
www.machineryhouse.com.au/SCJAN8

SYDNEY	BRISBANE	MELBOURNE	PERTH
(02) 9890 9111	(07) 3274 4222	(03) 9212 4422	(08) 9373 9999
1/2 Windsor Rd, Northmead	625 Boundary Rd, Coopers Plains	1 Fowler Rd, Dandenong	11 Valentine St, Kewdale

Specifications & Prices are subject to change without notification. All prices include GST and valid until 31-01-18

01_SC_020118